



**EAST WATERWAY OPERABLE UNIT
SUPPLEMENTAL REMEDIAL INVESTIGATION/
FEASIBILITY STUDY
HHRA TECHNICAL MEMORANDUM
FINAL**

For submittal to:

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Region 10
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Acronyms

ACRONYM	Definition
ABS	dermal absorption fraction
AF	adherence factor
ALM	Adult Lead Model
API	Asian and Pacific Islander
ATSDR	Agency for Toxic Substance and Disease Registry
BPJ	best professional judgment
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COPC	chemical of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSM	conceptual site model
CSO	combined sewer overflow
CT	central tendency
dw	dry weight
EPA	US Environmental Protection Agency
EPC	exposure point concentration
EW	East Waterway
FS	feasibility study
GSD	geometric standard deviation
HEAST	Health Effects Assessment Summary Tables
HHRA	human health risk assessment
HI	hazard index

ACRONYM	Definition
HQ	hazard quotient
IEUBK	Integrated Exposure Uptake Biokinetic Model for Lead in Children
IR	ingestion rate
IRIS	Integrated Risk Information System
LDW	Lower Duwamish Waterway
MIS	multi-increment sampling
MLLW	mean lower low water
MTCA	Model Toxics Control Act
NCP	National Contingency Plan
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEF	potency equivalency factor
Port	Port of Seattle
PPE	personal protective equipment
PPRTV	Provisional Peer-Reviewed Toxicity Values
PSAMP	Puget Sound Ambient Monitoring Program
QAPP	quality assurance project plan
RBC	risk-based concentration
RBTC	risk-based threshold concentration
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RL	reporting limit
RME	reasonable maximum exposure
SF	slope factor
SL	screening level
SMS	Washington State Sediment Management Standards
SRI	supplemental remedial investigation
TCDD	tetrachlorodibenzo- <i>p</i> -dioxin
TEF	toxic equivalency factor
TEQ	toxic equivalent
U&A	Usual and Accustomed
UCL	upper confidence limit on the mean
VOC	volatile organic compound

ACRONYM	Definition
WAC	Washington Administrative Code
WDFW	Washington State Department of Fish and Wildlife
WHO	World Health Organization
Windward	Windward Environmental LLC
WQA	water quality assessment
WSOU	Waterway Sediment Operable Unit
WW	West Waterway
ww	wet weight

1 Introduction

This technical memorandum outlines the framework for the baseline human health risk assessment (HHRA) for the East Waterway (EW) Operable Unit supplemental remedial investigation (SRI) and feasibility study (FS). This document describes the dataset available for conducting the risk assessment and the methods and approaches based on the US Environmental Protection Agency (EPA) HHRA guidance for conducting risk assessments under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). To the extent possible, this HHRA is consistent with the approach and methods that were approved by EPA for use in the HHRA for the Lower Duwamish Waterway (LDW) (2007c), which is upstream and contiguous with the EW.

This document describes methods which will serve as a roadmap for completion of the draft HHRA. EPA, the Tribes, and other stakeholders reserve the right to comment on all elements of the draft HHRA, including the methods. Further, it is noted that Tribal consultation is a dialogue process between the Tribes and EPA that will continue throughout the development of the HHRA.

Methods for conducting the exposure and toxicity assessments and the risk characterization are provided, including descriptions of exposure assumptions proposed for use in the HHRA. The process used to identify chemicals of potential concern (COPCs) for each medium is presented, and datasets and rules for data reduction (e.g., calculation of chemical group totals, treatment of reporting limits) that will be applied to the HHRA are also identified. Finally, likely issues for evaluation in the uncertainty assessment are discussed.

2 Data Availability

This section identifies the environmental data available for use in the HHRA and the process that will be used to select specific datasets for each medium:

- ◆ Surface sediment chemistry data
- ◆ Tissue chemistry data for clams (including geoducks), mussels, crabs, English sole, shiner surfperch, and brown rockfish
- ◆ Surface water chemistry data

Final data selected for use will be identified in the HHRA report. Rules regarding data reduction, derivation of chemical group totals, and treatment of undetected chemicals are described in Appendix A (data management). The HHRA will include a discussion of the comparison of non-detect data values to analytical concentration goals. Such comparisons have already been performed for the tissue data reports (Windward 2010a, b) and important findings will be summarized in the HHRA.

In addition to the EW data presented here for use in the EW HHRA, incremental risk estimates may be calculated for some chemicals. As was done in the LDW HHRA (Windward 2007c), this analysis may be presented in the risk characterization section of the EW HHRA. Because risks have not been calculated, it is not yet known exactly which chemicals will be associated with unacceptable risks and might be relevant for consideration of background contribution to risk and an evaluation of incremental risks. After completion of the risk assessment, [additional discussions will occur with EPA if incremental risk evaluations for chemicals other than arsenic are warranted](#). Options for addressing background contributions to risk, with specific examples of how arsenic background was evaluated for the LDW HHRA, are discussed further in Section 5.3.

2.1 SURFACE SEDIMENT CHEMISTRY

The following considerations will be made in selecting existing surface sediment data for the HHRA dataset:

- ◆ **Depth of sample** – Only sediment collected from 0 to 10 cm will be included.
Sampling date – Only data collected after 1994 will be included.
- ◆ **Dredging activities** – Only data collected from locations that were not subsequently dredged will be included.
- ◆ **Data quality** – Only data that have been validated and considered acceptable for risk assessment under CERCLA will be included (historical datasets were reviewed in the existing information summary report [EISR] (Anchor and Windward 2008)).

As reported in the existing information summary report (Anchor and Windward 2008), 14 previous investigations have involved the collection of surface sediment samples in the EW, for a total of 287 samples (Table 2-1). These sediment samples have been collected as part of post-dredge monitoring or nature and extent of contamination investigations. Nearly all of the surface sediment sampling locations are considered relevant and representative of current conditions. Samples not relevant for the HHRA include 32 surface samples representing areas that have been dredged and 34 samples that were collected as part of the recontamination monitoring sampling events in 2006 and 2007 from locations with contingency dredging and sand placement in the Phase 1A Removal Action. Two samples were collected from the 0-to-1-cm depth, thirty-two samples were collected from 0-to-2-cm depth, and the remaining samples were collected from 0-to-10-cm depth. Therefore, 221 samples that were collected from depths less than 10 cm, can be considered for use in the HHRA.

In addition to the substantial number of surface sediment samples that have been collected from the EW since 1994, more samples are being collected as part of the EW SRI (Table 2-1). A sampling design for the EW SRI data collection event in 2009 was provided in the surface sediment quality assurance project plan (QAPP) (Windward 2009a). The sampling plan was designed to build off existing acceptable sediment data in order to provide overall spatial coverage for EW. The SRI samples will include 95

subtidal and intertidal grab samples, 13 subtidal grab composite samples, and 4 intertidal multi-increment sampling (MIS) samples. Three of the MIS samples are intended to represent study area-wide intertidal areas. One of the MIS samples represents only intertidal areas publically accessible from the shore.

For estimating intertidal exposures, only the three study area-wide intertidal MIS samples or the single MIS sample for publically accessible intertidal areas will be used. No previously collected data will be used to estimate EW intertidal concentrations because the intertidal MIS samples are intended to be spatially representative of the site (Windward 2009a).

For estimating EW study area-wide sediment exposure concentrations, a separate estimate for the intertidal portion of the EW (using the three study area-wide MIS samples) will be combined with an estimate of subtidal exposure concentrations, using weighting factors to reflect the relative area of the intertidal versus subtidal portions of the EW. Details on the use of the two datasets together are provided in Section 3.3.4.2.

The use of specific samples from the historical data in combination with 2009 data for subtidal regions of EW (e.g., how samples taken from the same or similar locations will be handled) will be determined based on the project data rules, which have not yet been developed and agreed upon. For estimating subtidal exposures for all chemicals except dioxins/furans and PCB congeners, all subtidal samples determined to be appropriate based on the project data rules from those samples collected from 1994 to 2009 (except the 13 subtidal grab composite samples from 2009 and any intertidal samples) will be used. For estimating subtidal exposures for PCB congeners and dioxin/furan exposure concentration, only the 13 composite subtidal samples will be used because this sampling was designed to be representative of EW-wide subtidal concentrations for these chemicals (Windward 2009a).

Table 2-1. Summary of available and proposed surface sediment data for potential use in the EW HHRA

Year of Sample Collection	No. of Samples ^a	Analytes ^b	No. of Dredged Samples	Event Name	Source
2009	112 ^c	SMS, dioxins and furans, pesticides, TBT	0	EW SRI	Windward (2009a)
2007	3	SMS, dioxins and furans	0	PSAMP sampling	preliminary data
2007	24	DMMP	0	EW – Recontamination Monitoring 2007	Windward (2008b)
2007	7	SMS, pesticides, TBT	0	EW – Slip 27	Windward (2007a)
2006	21	DMMP	0	EW – Recontamination Monitoring 2006	Windward (2007b)
2005	13	SMS	0	USCG (Pier 36-37 slip and Berth Alpha)	Hart Crowser (2005)

Year of Sample Collection	No. of Samples ^a	Analytes ^b	No. of Dredged Samples	Event Name	Source
2005	53	SMS; DMMP	0	Phase 1A Removal Post-dredge Monitoring	Anchor and Windward (2005)
2001	43 ^d	SMS; DMMP	2	EW/Harbor Island Nature and Extent – Phases 1 and 2	Windward (2002)
2000	13	SMS; DMMP	0	T-18 – post-dredge monitoring	Windward (2001)
1997	3	SMS	3	Pier 36/37 – surface	Tetra Tech (1997)
1996	3	SMS	0	Pier 36 – underpier	Tetra Tech (1996)
1996	6	SMS	2	King County CSO 96	King County (1996)
1995	7	SMS	2	King County CSO 95	King County (1995)
1995	12	SMS	9	Harbor Island SRI	EVS (1996a, b)

^a The total number of samples analyzed as part of the original investigation within the East Waterway boundary, including samples that were characterized for removal but were subsequently not removed.

^b SMS analytes include PCBs, SVOCs, metals (arsenic, cadmium, chromium, copper, lead, mercury, silver, and zinc), TOC, and grain size; DMMP analytes include PCBs, pesticides, SVOCs, TBT, metals (antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc), VOCs, TOC, and grain size.

^c Samples will include 95 subtidal and intertidal grab samples, 13 subtidal grab composite samples, and 4 intertidal MIS samples.

^d Samples were collected from 43 locations. An undisturbed sediment aliquot, different from the homogenized sample submitted for other chemical analyses, was first removed from each sample for VOC analysis and given a sample identifier.

CSO – combined sewer overflow

DMMP – Dredged Material Management Program

EW – East Waterway

na – not available

MIS – multi-increment sampling

PCB – polychlorinated biphenyl

PSAMP – Puget Sound Ambient Monitoring Program

RI – remedial investigation

SMS – Washington Sediment Management Standards

SRI – supplemental remedial investigation

SVOC – semivolatile organic compound

T-18 – Terminal 18

TBT – tributyltin

TOC – total organic carbon

VOC – volatile organic compound

USCG – US Coast Guard

2.2 TISSUE CHEMISTRY

As reported in the EISR (Anchor and Windward 2008), five studies outside of the EW SRI/FS process (i.e., 2008 sampling) have reported tissue concentrations for fish and shellfish collected throughout the EW. English sole were analyzed by EVS Environment Consultants (EVS, unpublished), transplanted mussels were collected by King County (1999); red rock crab and striped perch were collected by Environmental Solutions Group (1999), and Windward Environmental LLC (Windward) collected and English sole, shiner surfperch, and rock fish (2005). PCBs, mercury, and TBT were the most frequently analyzed chemicals in tissue samples. King County (1999) conducted the only study with an extensive analytical list that included metals, organometals, SVOCs, PCBs, and pesticides. In addition, numerous samples of different tissue types were collected in 2008 as part of the EW RI/FS.

The tissue dataset for the EW HHRA is summarized in Table 2-2. All tissue data collected since 1994 is included. The largest dataset is the 2008 SRI sampling, which included the collection of English sole, brown rockfish, shiner surfperch, crabs, mussels, and clams. The Conceptual Site Model and Data Gaps Analysis Report (Anchor et al. 2008) evaluated the utility of existing data. The sampling design for the SRI tissue collection events with respect to the HHRA included the following considerations for data representativeness in the SRI:

- ◆ Species preferred for human consumption
- ◆ Availability of tissue types
- ◆ Age of the data

A data quality review will be conducted, and only those data that are considered acceptable based on data validation results will be included in the HHRA. Historical data were reviewed as part of the EISR. Only tissue data collected after 1994 will be included in the HHRA. In general, all tissue chemistry data of the same tissue type from all years will be weighted equally because there is no reason to expect that these samples cannot be used together (i.e., environmental conditions and chemical contamination are not expected to have changed substantially over the years of collection). Any potential differences in tissue chemical concentrations across years, and the impact of the inclusion of these data on the risk assessment, may be discussed in the uncertainty analysis. The specific details of how the tissue samples will be grouped to describe exposure (i.e., the consumption categories for which exposure point concentrations will be developed) are discussed in Section 3.3.4.

Table 2-2. Summary of available tissue data for potential use in the EW

Species	Year of Sample Collection	No. of Samples	No of Individuals per Sample	Sample Type	Analytes	Event Name	Reference
English sole	2008	11	5	whole body	PCBs Aroclors, pesticides, SVOCs, metals, inorganic arsenic, butyltins, lipids, dioxins and furans (subset of samples), PCB congeners (subset of samples)	EW-Fish Collection 2008	Windward (2008d)
		11	5	skin-on fillet			
	2005	2	5	skin-on fillet and remainder ^a	PCBs Aroclors, mercury, lipids,	EW-Fish Collection 2005	Windward (2005)
	1995	3	6 to 8	skinless fillet	PCBs Aroclors and subset of PCB congeners, butyltins, mercury, methylmercury, lipids,	EVS 95	Battelle (1996) and Frontier GeoSciences (1996)
Brown rockfish	2008	14	1	whole body	PCBs Aroclors, pesticides, SVOCs, metals, inorganic arsenic, butyltins, lipids, dioxins and furans (subset of samples), PCB congeners (subset of samples)	EW-Fish Collection 2008	Windward (2008d)
	2005	2	1		PCBs Aroclors, mercury, lipids,	EW-Fish Collection 2005	Windward (2005)
Shiner surfperch	2008	8	10	whole body	PCBs Aroclors, pesticides, SVOCs, metals, inorganic arsenic, butyltins, lipids, dioxins and furans (subset of samples), PCB congeners (subset of samples)	EW-Fish Collection 2008	Windward (2008d)
	2005	3	6 to 8		PCBs Aroclors, mercury, lipids,	EW-Fish Collection 2005	Windward (2005)
Striped perch	1998	3	2 to 8	skinless fillet	PCBs Aroclors, mercury, TBT, lipid	WSOU	ESG (1999)
	1998	3	2 to 8	skin-on fillet	PCBs Aroclors, mercury, TBT, lipid	WSOU	ESG (1999)
Dungeness crab ^b	2008	1	7	edible meat	PCB Aroclors, pesticides, SVOCs, metals, inorganic arsenic, butyltins, lipids, dioxins and furans (subset of samples), PCB congeners (subset of samples)	EW-Fish Collection 2008	Windward (2008d)
				hepatopancreas	PCB Aroclors, pesticides, SVOCs, metals, inorganic arsenic, butyltins, lipids, dioxins and furans (subset of samples), PCB congeners (subset of samples)	EW-Fish Collection 2008	Windward (2008d)

Species	Year of Sample Collection	No. of Samples	No of Individuals per Sample	Sample Type	Analytes	Event Name	Reference
Red rock crab ^b	2008	8	7	edible meat	PCB Aroclors, pesticides, SVOCs, metals, inorganic arsenic, butyltins, lipids, dioxins and furans (subset of samples), PCB congeners (subset of samples)	EW-Fish Collection 2008	Windward (2008d)
	1998	3	5		PCB Aroclors, mercury, TBT	WSOU	ESG (1999)
	2008	8	7	hepatopancreas	PCB Aroclors, pesticides, SVOCs, metals, inorganic arsenic, butyltins, lipids, dioxins and furans (subset of samples), PCB congeners (subset of samples)	EW-Fish Collection 2008	Windward (2008d)
Mussels	2008	11	89 to 101	soft tissue	PCB Aroclors, pesticides, SVOCs, metals, inorganic arsenic, butyltins, lipids, dioxins and furans (subset of samples)	EW-Fish Collection 2008	Windward (2008d)
	1997	3	50 to 100		PCB Aroclors, SVOCs, pesticides, metals, butyltins, lipids, solids	KC WQA	King County (1999)
	1996	3	50 to 100		PCB Aroclors, SVOCs, pesticides, metals, butyltins, lipids, solids	KC WQA	King County (1999)
Clams – butter	2008	7	6 to 15	soft tissue	PCB Aroclors, SVOCs, pesticides, metals, butyltins, lipids, solids, dioxins and furans (in two samples), PCB congeners (in two samples)	EW-Clam Survey	Windward (2008c)
Clams – littleneck	2008	2	4 to 9	soft tissue	PCB Aroclors, pesticides, metals, butyltins, lipids, solids	EW-Clam Survey	Windward (2008c)
Clams – cockle	2008	2	13 to 17	soft tissue	PCB Aroclors, SVOCs, pesticides, metals, butyltins, lipids, solids, dioxins and furans (in one sample), PCB congeners (in one sample)	EW-Clam Survey	Windward (2008c)
Clams – softshell (<i>Mya arenaria</i>)	2008	1	15	soft tissue	PCBs Aroclors SVOCs, pesticides, metals, butyltins, lipids, solids	EW-Clam Survey	Windward (2008c)
Geoduck ^c	2008	5	1	Edible meat	PCB Aroclors, SVOCs, pesticides, metals, butyltins, lipids, solids, dioxins and furans (subset of samples), PCB congeners (subset of samples)	EW-Clam Survey	Windward (2008c)

Species	Year of Sample Collection	No. of Samples	No of Individuals per Sample	Sample Type	Analytes	Event Name	Reference
	2008	3	3	Gut ball	PCB Aroclors, SVOCs, pesticides, metals, butyltins, lipids, solids, dioxins and furans (subset of samples), PCB congeners (subset of samples)	EW-Clam Survey	

- ^a The results for the fillet composite samples and the remainder composite samples were weighted based on the fraction of the whole-body mass represented by each sample in order to calculate whole-body results (Windward 2006).
- ^b Data from hepatopancreas composite samples will be mathematically combined with data from composite samples of edible meat to form composite samples of edible meat plus hepatopancreas. Whole-body (i.e., edible meat plus hepatopancreas) crab concentrations will be calculated using the relative weights and concentrations of the edible meat and hepatopancreas.
- ^c Data from gut ball composite samples will be mathematically combined with data from edible-meat composite samples to form composite samples of edible meat plus gut ball. Whole-body (i.e., edible meat plus gut ball) geoduck concentrations will be calculated using the relative weights and concentrations of the edible meat and gut ball.

ERA – ecological risk assessment
ESG – Environmental Solutions Group
EW – East Waterway
KC – King County
nd – not determined
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl

QAPP – quality assurance project plan
SVOC – semivolatile organic compound
TBD – to be determined
TBT – tributyltin
WSOU – Waterway Sediment Operable Unit
WQA – water quality assessment

2.3 SURFACE WATER CHEMISTRY

As reported in the EISR (Anchor and Windward 2008), the previously collected surface water chemistry data for the EW are from three investigations (Table 2-3). One event was conducted by King County as part of their combined sewer overflow (CSO) water quality assessment (WQA) for the Duwamish River and Elliott Bay (King County 1999a) and includes an extensive amount of surface water data from the EW. The other two events were water quality monitoring carried out during dredging events conducted in 2000 and 2004-2005. The relatively small number of samples in these last two studies, as well as the elevated analytical reporting limits (RLs), restricts the usability of these datasets for the risk assessments. Therefore, the data from the 2000 and 2004-2005 events can be used in the discussion of nature and extent of contamination in the SRI (Windward 2009b) but will not be used for HHRA.

Data were also collected in 2008-2009 specifically for the SRI/ FS for the EW (Anchor and Windward 2008) (Table 2-3). Surface water sampling for the SRI/FS was designed to represent a variety of environmental conditions (i.e., habitats, seasons, depths, and flow rates) in the EW. The 1996-1997 WQA conducted by King County represents the majority of the available surface water data. For that study, King County conducted sampling in the EW on a weekly basis from October 1996 to June 1997, for a total of 192 samples. These data represent a substantial dataset and, therefore, will be used with data from the SRI/FS event to describe surface water conditions. Once all risk assessment datasets have been compiled, an analysis of the King County water data will be conducted to evaluate estimates of the mean and the upper confidence limit on the mean (UCL), to evaluate similarities and differences in the variability of the two datasets, and to evaluate the magnitude of any differences before determining how the data will be used in the HHRA. The purpose of this evaluation is to determine whether or not the historical dataset is representative of current conditions. The surface water dataset and its use in the HHRA will be discussed with EPA prior to completion of the draft HHRA.

Table 2-3. Summary of available surface water data for use in the EW HHRA

Year of Sample Collection	No. of Samples Analyzed	Analytes	Event Name	Source
2008-2009	49	metals (filtered and unfiltered), PCBs congeners, SVOCs, TBT, and conventionals	SRI/FS	Windward (2009b)
2004-2005	36 ^a	metals (unfiltered), PCBs (Aroclors), pesticides (dieldrin and DDT), TBT, and conventionals	2005 EW Water Quality Monitoring	Anchor and Windward (2005)
2000	6	metals (unfiltered), PCBs (Aroclors), pesticides (aldrin, dieldrin, DDT, and chlordane), TBT, and conventionals	2000 EW Water Quality Monitoring	SEA (2000)

Year of Sample Collection	No. of Samples Analyzed	Analytes	Event Name	Source
1996-1997	192 ^a	metals (filtered and unfiltered), SVOCs, and conventionals	King County Water Quality Assessment	King County (1999)

^a Samples analyzed for conventional parameters only are not included in sample count.

EW – East Waterway

SRI – supplemental remedial investigation

FS – feasibility study

SVOC – semivolatile organic compound

HHRA – human health risk assessment

TBT – tributyltin

PCB – polychlorinated biphenyl

3 Exposure Assessment

This section presents a summary of the conceptual site model (CSM) for the HHRA, the process for chemical screening and evaluation, including exposure point concentration (EPC) calculation and COPC selection, details of the human health exposure scenarios, and the process for the calculation of chronic daily intake values.

3.1 CONCEPTUAL SITE MODEL AND SELECTION OF SCENARIOS FOR QUANTIFICATION

A CSM is a graphical representation of exposure media, transport mechanisms, exposure pathways, exposure routes, and potentially exposed human populations. It provides the basis for developing exposure scenarios to be evaluated in the exposure assessment component of the HHRA.

3.1.1 Conceptual site model

A detailed version of the EW HH CSM was previously presented in the CSM and data gaps memo, which was approved by EPA (Anchor et al. 2008). A summary is provided here to give context (i.e., the exposure pathways) to the exposure scenarios described in Section 3.3. The exposure assessment focuses only on scenarios that include a direct (i.e., ingestion or dermal contact) or indirect (i.e., consumption of fish or shellfish) pathway of exposure to chemicals in sediments, water, or biota in the EW (Figure 3-1). Details on exposures scenarios, including the identification of receptors (e.g., children, adults, residents, workers) are provided in Section 3.1.2. Section 3.1.2 also presents the rationale for the selection or exclusion of specific scenarios for evaluation in the risk characterization. Full details of the specific scenarios developed for evaluation in the risk characterization are provided in Section 3.3.

For each exposure pathway and media combination in the EW CSM, a determination was made in the CSM report (Anchor et al. 2008) as to whether the pathway is complete or incomplete. A complete exposure pathway includes the following components: an exposure medium, an exposure point, a potentially exposed population, and an exposure route. Pathways that do not include all four components are incomplete.

Incomplete pathways cannot be evaluated quantitatively in the risk assessment because both exposure (i.e., a complete pathway) and toxicity information are required to quantify risk. An example of an incomplete pathway for the EW is surface water as a source of drinking water for people. The saline conditions of the EW prevent this from being a complete pathway. Surface water exposure pathways are indirectly linked to sediment via flux from sediment to the water (Figure 3-1). For simplicity, the inhalation pathway is not shown in Figure 3-1 because it is considered insignificant (Anchor et al. 2008).

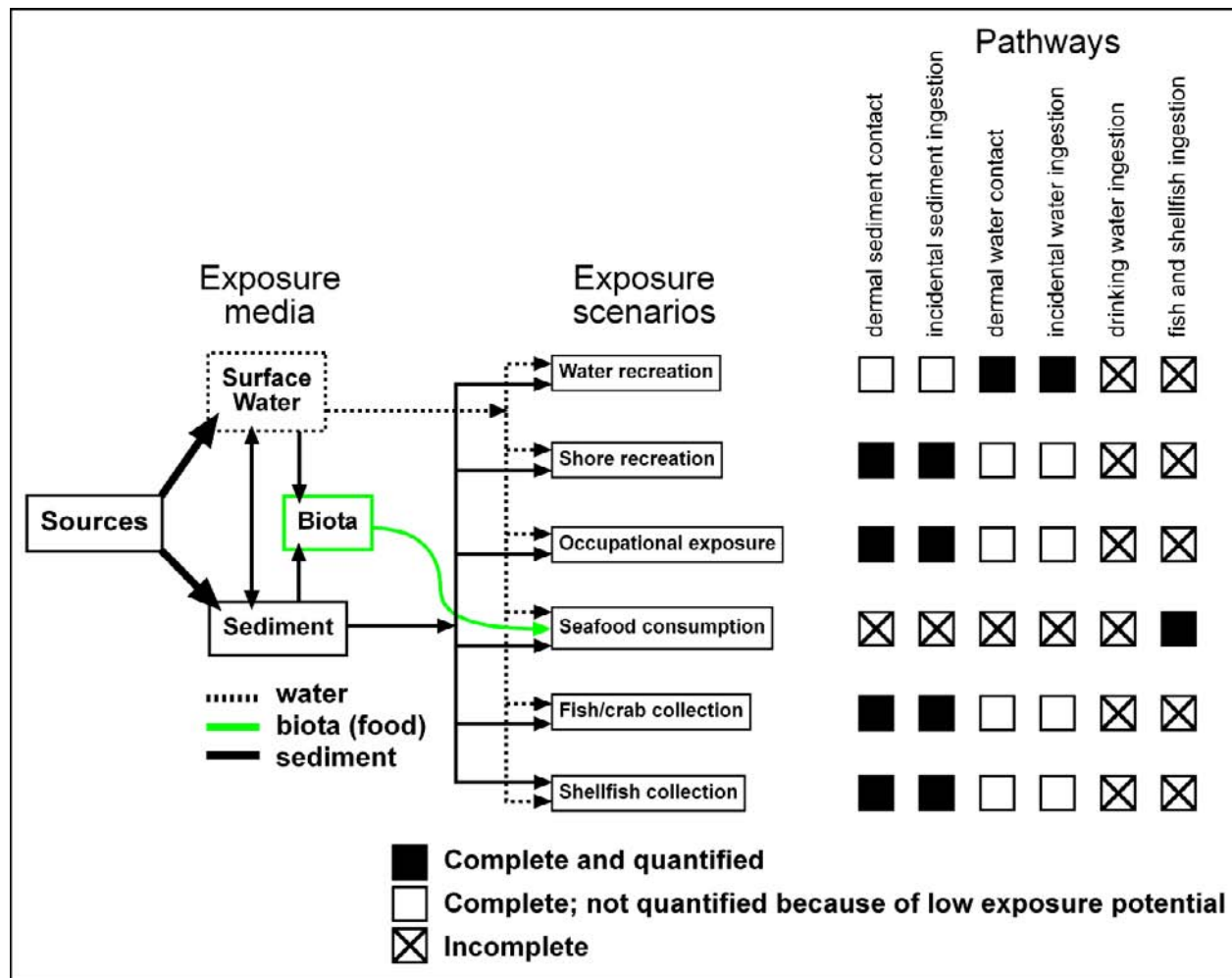


Figure 3-1. Conceptual site model for the human health risk assessment

The combined risk associated with all complete exposure pathways that have the greatest exposure potential will be evaluated in the HHRA. Some pathways identified as complete but with low exposure and risk potential relative to other evaluated pathways (e.g., exposure to water during shore clamming) may be discussed qualitatively in the HHRA (in the uncertainty section) for risk communication purposes. The qualitative assessment of pathways with low exposure potential is appropriate

because such pathways have minimal potential for causing excess risk or adverse health effects.

Six general exposure scenarios are presented in the HHRA CSM (Figure 3-1). Detailed exposure parameters for each scenario to be evaluated are presented in Section 3.3. Each exposure scenario involves at least one potential exposure pathway to contaminated sediments (e.g., dermal contact with sediments or incidental ingestion of sediments) or water and a potential exposure route through which contaminants can enter the body of an exposed individual (e.g., dermal absorption of contaminants through exposed skin surfaces or gastrointestinal absorption of ingested contaminants). However, the importance of some pathway and route combinations may be minor (i.e., low exposure potential), or the pathways may be incomplete. The scenarios presented are not mutually exclusive, and combinations of different pathways may be considered in the HHRA.

Several levels of exposure scenarios will be used in the risk assessment to describe different intensities (e.g., frequency, magnitude, and duration) of site use or seafood consumption. The different levels of exposure will provide a range of exposure and risk information for a given exposure scenario for use by the risk manager. This risk assessment includes four different levels of exposure. The reasonable maximum exposure (RME) level describes exposures well above the average but still within the range of those possible. EPA generally uses RME scenarios to evaluate remedial actions at a site (EPA 1989). RME by definition likely overestimates exposure for many individuals (EPA 1989). Central tendency (CT) risk estimates are intended to reflect risk associated with average exposures¹. Average exposure estimates are not favored in decision-making because they will underestimate exposure for a substantial number of individuals (EPA 1989). The upper-bound level is likely to fall at or above the highest exposures likely to occur. The upper-bound level is used in two ways: to show that exposure pathways are not important sources of exposure and risk and to provide a ceiling for risks associated with a given exposure scenario. As determined through consultation between the tribes and EPA and for consistency with the LDW HHRA (Windward 2007c), the Suquamish seafood consumption scenario will be presented in this context.² Finally, the unit exposure level is used to describe a baseline against which people can assess their own individual exposure potential. Unit exposures (e.g., one meal of seafood per month) are not intended to characterize any specific receptor and are presented for informational purposes.

¹ In the EW HHRA, CT risks estimates will only be evaluated for specific exposure populations (e.g. Asian and Pacific Islander consumption of seafood) as described in Sections 3.3.1 and 3.3.2. This HHRA will not attempt to provide CT risk estimates for the general population.

² Per the EPA tribal framework guidance for assessing tribal risks (EPA 2007b), the selection of seafood consumption scenarios is determined through consultation between the tribes and EPA. The selection of specific scenarios for evaluation at specific locations has no bearing on harvest treaty rights and has no implications regarding tribal harvest of seafood now or in the future.

For some pathways, both RME scenarios and CT scenarios were developed to describe some of the range of possible exposures and risks. The exposure parameters for each scenario and exposure level (i.e., RME, CT, upper bound, and unit exposure) are discussed in detail in Section 3.3, and risk estimates for scenarios associated with each of these levels will be presented in the risk characterization portion of the risk assessment.

3.1.2 Selection of exposure scenarios for quantification

Specific exposure assumptions will be developed to quantify the complete pathways with significant exposure potential shown in Figure 3-1. A complete exposure pathway includes an exposure medium, exposure point, a potentially exposed population (including age category [i.e., adult versus child]), and an exposure route. Separate scenarios for current and future land use will not be evaluated for the following reasons:

- ◆ Future land use within the EW is not expected to differ greatly from current land use (POS 2007). The use of the EW for commercial and industrial purposes is expected to continue into the foreseeable future, although certain recreational activities that are consistent with these land uses may be more common in the future as habitat improves.
- ◆ Because site-specific parameters based on current land use practices are not always available, reasonable maximum values will be selected. These parameters are also intended to account for potential future use; therefore these values will overestimate current exposure but will be derived to provide information to risk managers that will allow them to evaluate risk assuming increased site exposure in the future.
- ◆ Tribal harvest of seafood, as a treaty-reserved right, is now and will continue to be unrestricted.

Summing risks from multiple exposure pathways is reasonable if multiple pathways are relevant to the same person or group of people. EPA (1989) suggests that summing risks from multiple RME scenarios that do not occur simultaneously could be overly conservative. Several summed scenarios will be assessed in the risk characterization (e.g. clamming and seafood consumption). Although CT scenarios for netfishing and seafood consumption are available, the netfishing RME scenario will be summed with a seafood consumption RME scenario when evaluating risks across different exposure pathways because these activities are not mutually exclusive, and both could be practiced by some individuals.

Details of each exposure pathway were provided in the CSM and data gaps report (Anchor et al. 2008). Table 3-1 summarizes the decision process for selecting exposure pathways for quantification. Details of each scenario to be evaluated in the HHRA are provided in Section 3.3. It is possible that EW cleanup decisions could be based on a combination of excess cancer risks and non-cancer hazard estimates from different

exposure scenarios, particularly if reducing risks to acceptable levels for all RME scenarios is not possible. Therefore, the exposure scenarios to be evaluated in the HHRA are expected to provide risk information for pathways/scenarios with risks within the acceptable range, as well as for scenarios with the highest risks.

For some scenarios designated for qualitative analysis because their exposures are expected to be substantially less than those for other scenarios (e.g., sediment exposure for swimmers or surface water exposure for habitat restoration workers), example calculations may be performed to demonstrate how these exposures relate to scenarios that will be evaluated quantitatively. For example, cancer risks for surface water exposure of swimmers may be scaled to roughly estimate cancer risks for surface water exposure of habitat restoration workers; similarly, cancer risks for sediment exposure for habitat restoration workers may be scaled to roughly estimate cancer risks for sediment exposure to swimmers. However, such quantitative scaling of risk estimates will not be performed for scenarios deemed not applicable to the EW (e.g., recreational activities such as dog walking along the shore).

Table 3-1. Rationale for the selection or exclusion of exposure pathways by exposure scenario

Exposure Point	Exposure Medium	Exposed Population	Age Category	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Water Recreation						
Water recreation areas in the EW	Sediment	Resident	adult	dermal, ingestion ^a	qualitative	Exposure via swimming is lower than exposure via other pathways.
			child	dermal, ingestion ^a	qualitative	Exposure via swimming is lower than exposure via other pathways.
	Surface water	Resident	adult	dermal, ingestion ^b	numeric	The extent of swimming in the EW is unknown but expected to be low (King County 1999). Potential exposure from swimming will be evaluated using recently collected surface water data and exposure parameters developed by King County (King County 1999).
			child	dermal, ingestion ^b	numeric	The extent of swimming in the EW is unknown but expected to be low (King County 1999). Potential exposure from swimming will be evaluated using recently collected surface water data and exposure parameters developed by King County (King County 1999).
Shore Recreation						
Exposed EW intertidal areas	Sediment	Resident	adult	dermal, ingestion ^a	qualitative	There are no residential areas adjacent to or within a few blocks of EW public access areas, and areas of tidally exposed sediment at public access locations are relatively small. The non-tribal clamming scenario is expected to be protective of any shore recreation activities.
			child	dermal, ingestion ^a	qualitative	There are no residential areas adjacent to or within a few blocks of EW public access areas, and areas of tidally exposed sediment at public access locations are relatively small.
	surface water	Resident	adult	dermal, ingestion ^b	qualitative	Exposure attributable to resuspended sediment in water column is insignificant compared with that from direct contact with bedded sediment. Exposure is expected to be much lower than that evaluated in the swimming scenario.
			child	dermal, ingestion ^b	qualitative	Exposure attributable to resuspended sediment in water column is insignificant compared with that from bedded sediment. Exposure is expected to be much lower than that evaluated in the swimming scenario.

Exposure Point	Exposure Medium	Exposed Population	Age Category	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Occupational Exposure						
Industrial facilities adjacent to the EW	sediment	Worker	adult	dermal, ingestion ^a	qualitative	Exposure is expected to be much lower than that evaluated in the habitat restoration sediment exposure scenario.
	surface water	Worker	adult	dermal, ingestion ^b	qualitative	Exposure expected to be much less than that evaluated in the swimming scenario.
Habitat restoration and EW cleanup locations	sediment	Worker	adult	dermal, ingestion ^a	numeric	Workers engaged in habitat restoration or site cleanup projects may come in contact with sediment. Risk estimates will help to identify what level of PPE is appropriate for these workers.
	surface water	Worker	adult	dermal, ingestion ^b	qualitative	Exposure is expected to be much less than that evaluated in the swimming scenario.
Fish and Crab Collection						
Commercial netfishing locations in the EW, which potentially include all EW sediments	sediment	Worker	adult	dermal, ingestion ^a	numeric	Commercial fishers are active at the site throughout the fishing season; nets contact the sediment.
	surface water	Worker	adult	dermal, ingestion ^b	qualitative	Exposure attributable to resuspended sediment in the water column is insignificant compared to that from bedded sediment.
Fishing locations in the EW	sediment	Resident	adult	dermal, ingestion ^a	qualitative	Exposure is difficult to quantify, and likely to be lower than occupational exposure. Incidental exposure during finfishing and crabbing is insignificant.
	surface water	Resident	adult	dermal, ingestion ^b	qualitative	Incidental exposure is insignificant.
Shellfish Collection						
Exposed EW intertidal areas	sediment	Resident	adult	dermal, ingestion ^a	numeric	Tribal members and members of the general public may have interest in clamming intertidal clamming the EW now or in the future. Non-tribal clamming will be limited to areas with intertidal sediment the public can access by foot. Tribal clamming will include all intertidal areas with exposed sediment. Several clamming exposure scenarios will be evaluated in the EW HHRA.
	surface water	Resident	adult	dermal, ingestion ^b	qualitative	Exposure attributable to resuspended sediment in the water column is insignificant compared to that from bedded sediment. Exposure is expected to be much lower than that evaluated in the swimming scenario.

Exposure Point	Exposure Medium	Exposed Population	Age Category	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Human Consumption of Resident Seafood						
Site-wide	resident fish and shellfish tissue (biota)	Resident ^c	adult, child	ingestion	numeric	Tribal fish and shellfish consumption will be evaluated based on consultation between EPA and the Tribes. An API consumption scenario will be evaluated using consumption rates derived from a recent survey of the API community (Kissinger 2005). Some subsistence harvesting may also occur in the EW, and the public has recreational expectations for a fishable and swimmable estuary. A one-meal-per-month consumption scenario will be evaluated to provide individuals with a scalable tool to assess risks associated with their consumption habits.

^a Incidental sediment ingestion associated with dermal contact.

^b Incidental water ingestion associated with dermal contact.

^c Resident may include Asian and Pacific Islanders, Tribal members, transients, or recreational fishers. Some of the different fish consuming populations are described in Section 3.3.1.

API – Asian and Pacific Islander

EPC – exposure point concentration

EPA – US Environmental Protection Agency

EW – East Waterway

HHRA – human health risk assessment

PPE – personal protective equipment

TBD – to be determined

3.2 CHEMICAL SCREENING AND EVALUATION

In order to focus the risk assessment on chemicals of potential concern (COPCs), a screening step will be performed. The identification of general exposure pathways based on the CSM is necessary to screen appropriately. Only chemicals that pass this initial screening process (i.e., COPCs) will be evaluated in the risk assessment. Exposure associated with COPCs will then be evaluated quantitatively for the scenarios described in Section 3.3.

3.2.1 Identification of chemicals of potential concern

A comprehensive set of chemicals is being analyzed in sediment, water and tissue collected from the EW as described in Section 2. In accordance with EPA (1996) guidelines, risk-based screening will be conducted on these data to determine which chemicals should be quantitatively evaluated in the baseline HHRA. Screening helps to focus the HHRA on the parameters that may pose a risk.

The decision process for identifying COPCs is shown in Figure 3-2. This is similar to the process that was used in the LDW HHRA (Windward 2007c) for sediment and tissue. For detected chemicals with values in EPA's Regional Screening Levels (RSL) for Chemical Contaminants at Superfund Sites (EPA 2009b)³, the maximum detected concentration will be compared to the applicable RSL (Step 3a). RLs will also be evaluated relative to the RSLs for chemicals that had maximum detected concentrations that do not exceed the RSLs, as shown in Figure 3-2 (Steps 4a and 4b). If a chemical is detected in greater than 10% of the samples, and those detected values never exceed the RSL, the chemical will be excluded from further analysis. For those chemicals with a detection frequency less than 10%, the number of times the RL exceeds the RSL will be determined (the right side of Figure 3-2; Step 4b). If RLs exceed the RSL with a frequency greater than 10% (Step 4b), that will be considered sufficient uncertainty that the RSL may be exceeded, and the chemical will be retained as a COPC. Risks related to COPCs identified based on RLs greater than RSLs alone will be considered in the uncertainty analysis of the risk assessment. Chemicals without RSLs will not be screened or quantitatively evaluated but will be considered in the uncertainty analysis. Details on the selection of RSLs by media are discussed in Sections 3.2.1.1 through 3.2.1.3.

³ The LDW HHRA was completed prior to creation of EPA's RSLs (EPA 2009b). For the LDW HHRA, regional Preliminary Remediation Goals (PRGs) were used to screen COIs. EPA's RSLs include many of the regional PRGs. The differences between the EW and LDW screening processes are discussed for sediment in Section 3.3.2.1 and for tissue in Section 3.3.2.2.

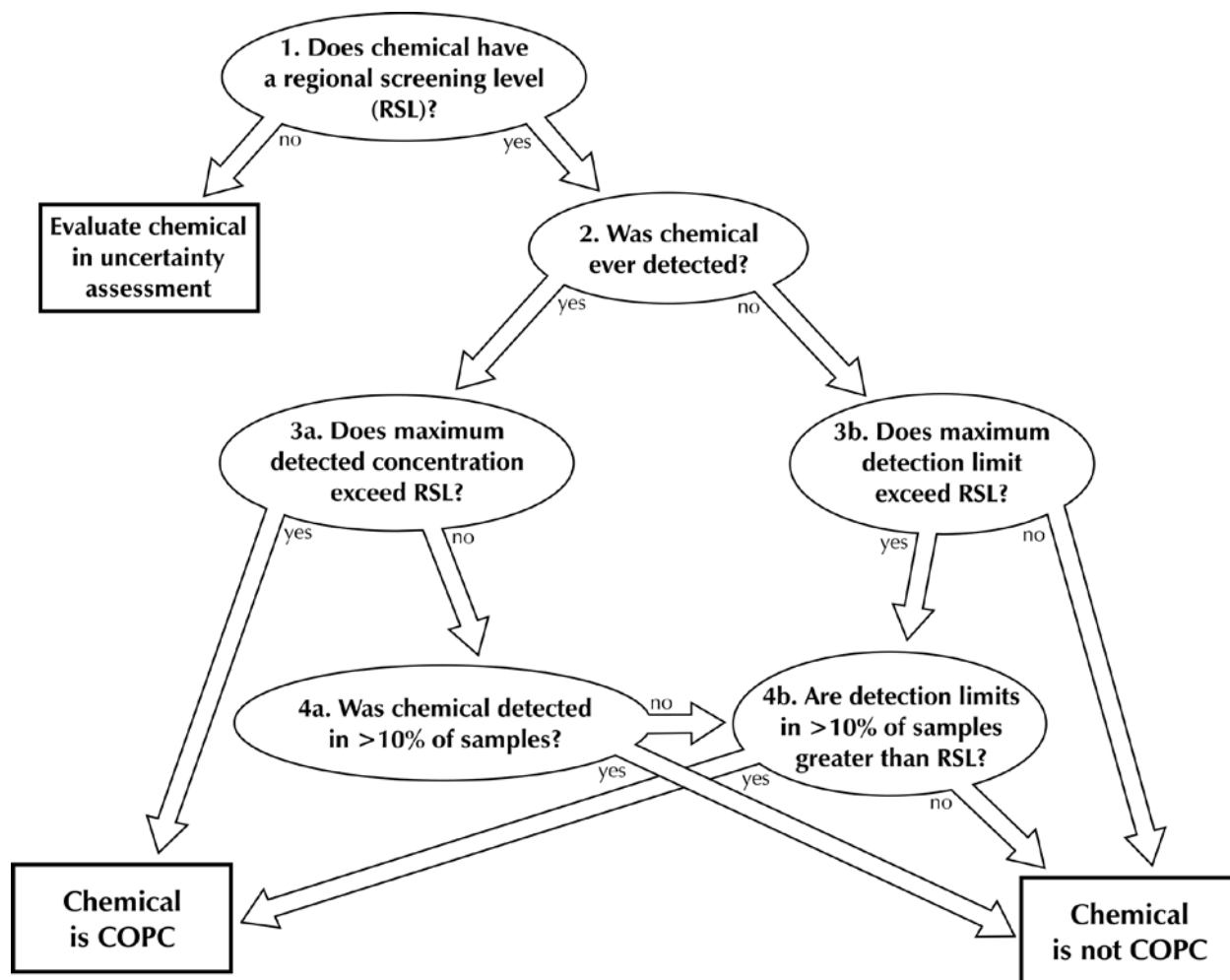


Figure 3-2. COPC identification flow chart

Some chemicals (e.g., carcinogenic polycyclic hydrocarbons [cPAHs] and polychlorinated dibenzodioxins and dibenzofurans) will be evaluated as groups, rather than individual compounds, using the toxic equivalent (TEQ) approaches described in Section 3.2.2. Screening will be conducted separately for sediment direct, seafood consumption, and water direct contact exposures. Human Health COPCs identified for the EW will be compared to those identified in the LDW HHRA.

3.2.1.1 Screening sediment data

EPA's RSLs for Chemical Contaminants at Superfund Sites (EPA 2009b) provides soil RSLs intended to be protective of human health risk in screening both industrial and residential scenarios. The equations used to calculate the RSLs incorporate exposure via ingestion, skin contact, and inhalation simultaneously. RSLs for chemicals with non-carcinogenic effects will be decreased by a factor of 10 to account for the target hazard quotients (HQs) of 0.1 used in screening by EPA Region 10. Both residential and industrial RSLs will be used in the screening. Residential RBCs will be applied to the clamming scenarios; industrial RBCs will be applied to the habitat restoration and

netfishing scenarios. The soil RSLs are an update of the Region 9 preliminary remediation goals (PRGs) (2004a), the Region 9 PRGs were used for sediment COPC screening for the LDW HHRA (Windward 2007c).

3.2.1.2 Screening tissue data

COPCs in fish and shellfish tissue will be identified by comparing EW concentrations against RSLs for fish tissue developed using EPA's RSL calculator (EPA 2009c). Default exposure factors for fish RSLs include: target HQ = 1, target excess cancer risk = 10^{-6} , body weight = 70 kg, exposure frequency = 350 days per year, exposure duration = 30 years, and fish ingestion rate = 54 g/day (EPA 2009b). These exposure factors are consistent with Region 10 guidance for performing risk assessments (EPA 1996), with the exception of the target HQ. Region 10 recommends a target HQ of 0.1 to account for cumulative effects from multiple chemicals and pathways. RSLs for chemicals with non-carcinogenic effects were therefore decreased by a factor of 10 (using the site specific option of the RSL calculator) to be consistent with guidance from EPA Region 10.

In addition to the modification described above for target HQ, the RSLs for both carcinogenic and non-carcinogenic endpoints will be modified using the RSL calculator (EPA 2009c) to account for site-specific tribal exposure assumption differences in consumption rate (97.5 g vs. 54 g; see Section 3.3), exposure frequency (365 days vs. 350 days), body weight (81.8 kg vs. 70 kg), and exposure duration (70 years vs. 30 years). The fish tissue RSLs are an update of the Region 3 Risk Based Concentrations (RBCs) (EPA 2005b). The Region 3 RBCs were used for screening the LDW tissue (Windward 2007c) with the same adjustments to HQ, exposure frequency, exposure duration, and body weight described above (Windward 2007c).

3.2.1.3 Screening water data

For water, data will be screened against the analytical concentration goals developed for the *Quality Assurance Project Plan: Surface Water Collection and Chemical Analysis* (Windward 2009b), which were derived from tap water screening levels developed by EPA (EPA 2007d) and are based on an assumed ingestion rate of 2 L/day. The analytical concentration goals from the QAPP will be used in the screening process for water in the same way RSLs will be used for sediment and tissue.

3.2.2 Calculation of sums and totals for chemical mixtures

The approach for calculating sums and total for chemical mixtures will be consistent with the approach used for the LDW HHRA (Windward 2007c). Concentrations for several analyte sums will be calculated as follows:

- ◆ Total PCBs will be calculated using only detected concentrations for seven Aroclor mixtures (1016, 1221, 1232, 1242, 1248, 1254, and 1260) in accordance with Washington State Sediment Management Standards (SMS) (Washington Administrative Code [WAC] 173-204). For individual samples in which none of the seven Aroclor mixtures was detected, total PCBs will be given a value equal

to the highest RL of the seven Aroclors. Total PCBs based on congeners will also be calculated using only detected concentrations for the PCB congeners. EPA often uses one-half the sample-specific RL for non-detects for HHRA in cases where particular Aroclors or congeners were detected elsewhere at the site (in the same medium). The SMS approach was used for deriving total PCBs to avoid the complexity of having different data sets for the HHRA and the ERA. Section 6.0 describes how the use of one-half the RL for non-detects detected elsewhere at the site will be explored in the uncertainty section.

- ◆ TEQs will be used for totaling certain groups of chemicals, specifically dioxin/furan TEQ, PCB TEQs, and cPAHs. The 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) toxic equivalency factors (TEFs) for coplanar PCBs and certain polychlorinated dibenzo-*p*-dioxin or furan (dioxin and furan) congeners are presented in Table 3-2. The TEFs relate the toxicity of the co-planar PCB congeners and certain dioxin and furan congeners to the toxicity of 2,3,7,8-TCDD. Similarly, potency equivalency factors (PEFs) relate the toxicity of certain polycyclic aromatic hydrocarbon (PAH) compounds to that of benzo(a)pyrene. PEFs for cPAHs are also shown in Table 3-2. PCB TEQ, dioxin/furan TEQ, and cPAH totals were calculated for each sample by summing the products of the concentrations of each individual congener or compound and its specific TEF or PEF for each group (PCB TEQ, dioxin/furan TEQ, and cPAHs, respectively). Congeners or compounds that are undetected for a given sample will be assigned a value equal to one-half the sample-specific RL for use in the TEQ calculation.
- ◆ Total DDTs will be calculated from detected concentrations of three to six isomers: 2,4'-DDD, 2,4'-DDE, 2,4'-DDT, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT. For samples in which all individual isomers are undetected, the single highest RL for that sample will be assigned to represent the sum of the three to six isomers.

Table 3-2. Toxic equivalency and potency equivalency factors for dioxins/furans, PCB congeners, and cPAHs

Compound	Toxic Equivalency or Potency Equivalency Factor
Dioxins and furans^a	
2,3,7,8-tetrachlorodibenzo- <i>p</i> -dioxin	1
1,2,3,7,8-pentachlorodibenzo- <i>p</i> -dioxin	1
1,2,3,6,7,8-hexachlorodibenzo- <i>p</i> -dioxin	0.1
1,2,3,4,7,8-hexachlorodibenzo- <i>p</i> -dioxin	0.1
1,2,3,7,8,9-hexachlorodibenzo- <i>p</i> -dioxin	0.1
1,2,3,4,6,7,8-heptachlorodibenzo- <i>p</i> -dioxin	0.01
Octachlorodibenzo- <i>p</i> -dioxin	0.0003
2,3,7,8-tetrachlorodibenzofuran	0.1
1,2,3,7,8-pentachlorodibenzofuran	0.03

Compound	Toxic Equivalency or Potency Equivalency Factor
2,3,4,7,8-pentachlorodibenzofuran	0.3
1,2,3,6,7,8-hexachlorodibenzofuran	0.1
1,2,3,7,8,9-hexachlorodibenzofuran	0.1
1,2,3,4,7,8-hexachlorodibenzofuran	0.1
2,3,4,6,7,8-hexachlorodibenzofuran	0.1
1,2,3,4,6,7,8-heptachlorodibenzofuran	0.01
1,2,3,4,7,8,9-heptachlorodibenzofuran	0.01
Octachlorodibenzofuran	0.0003
PCB congeners^a	
PCB-77	0.0001
PCB-81	0.0003
PCB-105	0.00003
PCB-114	0.00003
PCB-118	0.00003
PCB-123	0.00003
PCB-126	0.1
PCB-156	0.00003
PCB-157	0.00003
PCB-167	0.00003
PCB-169	0.03
PCB-189	0.00003
cPAHs^b	
Benzo[a]pyrene	1
Benzo[a]anthracene	0.1
Benzo[b]fluoranthene	0.1
Benzo[k]fluoranthene	0.1
Chrysene	0.01
Dibenz[a,h]anthracene ^c	0.4
Indeno[1,2,3-cd]pyrene	0.1

^a TEFs for dioxin and furans and PCB congeners from the World Health Organization (Van den Berg et al. 2006).

^b PEFs for cPAHs were defined by the California EPA, Office of Environmental Health Hazard Assessment (California EPA 1994). PEFs are available for PAHs that were not analyzed in EW sediments or tissue. The PEFs for these compounds are not shown here and are not used in this risk assessment.

^c The PEF was determined by California EPA by dividing the inhalation unit risk factor for this compound by the inhalation unit risk factor for benzo[a]pyrene.

cPAH – carcinogenic polycyclic aromatic hydrocarbon

PCB – polychlorinated biphenyl

PEF – potency equivalency factor

TEF – toxic equivalency factor

3.3 SELECTION OF EXPOSURE PARAMETERS AND CALCULATION OF CHRONIC DAILY INTAKE

The exposure scenarios to be quantified in the EW HHRA are summarized in Sections 3.3.1 (seafood ingestion)-, 3.3.2 (sediment exposure), and 3.3.3 (water exposure). Each section includes summary tables containing key exposure parameters,⁴ so that the scenarios can be compared to each other, and detailed tables in which all exposure parameters for each scenario are given. Exposure point concentrations (EPCs) will be calculated as chemical concentrations in water, sediment, and tissue for the various exposure scenarios following the procedure outlined in Section 3.3.4. The exposure parameters are used in conjunction with the EPCs calculated for COPCs to estimate chronic daily intakes (CDIs).

CDI rates represent the estimated daily chemical dose for an individual averaged over the exposure duration for each scenario. Separate CDIs will be calculated for chemicals with carcinogenic and non-carcinogenic effects because the averaging times over which the doses are calculated are different. The CDI results will be used in the risk characterization and uncertainty analysis.

3.3.1 Seafood exposure scenarios and parameters

The EW is an important commercial salmon fishery. However, because of the migratory nature of salmon, bioaccumulative chemicals found in adult salmon tissue are largely due to exposures from the open ocean and Puget Sound, where they spend much of their life, rather than chemicals present in the EW (Windward 2007c). Therefore, salmon consumption will not be included in this risk assessment, consistent with the HHRA for the LDW. The uncertainty analysis will include a discussion of uncertainties in the risk estimates resulting from the exclusion of the consumption of salmon.

Seafood collection in the EW is carried out by tribal members and the general public. Some information suggests that other relatively high seafood -consuming populations may use the EW for at least part of their seafood collection (EPA 1999a; King County 1999). A total of eight scenarios, including RME and CT scenarios, were developed and parameterized to represent a range of potential exposures via the consumption of EW seafood by different groups.

EPA Region 10 has developed tribal seafood consumption scenarios for application to CERCLA and Resource Conservation and Recovery Act (RCRA) sites in Puget Sound and the Strait of Georgia based on seafood consumption studies of the Tulalip Tribes and the Suquamish Tribe (EPA 2005a, 2007b). In these guidance documents, EPA specifies consumption rates for some tribal members for each type of seafood (i.e., seafood category). The adult tribal seafood consumption RME scenario follows the approach in the LDW HHRA to use the Tulalip seafood consumption survey data to

⁴ Summary tables are provided for seafood consumption and direct sediment exposure scenarios. No summary table is provided for swimming because only one scenario will be evaluated.

characterize adult tribal RME and tribal child seafood consumption. The Suquamish and Muckleshoot Tribes recognize that background concentrations for risk driver COCs, such as PCBs, will likely be the cleanup goals for both the LDW and EW sites and hence did not oppose the use of Tulalip rates to characterize seafood consumption risks for the EW. As was done for the LDW HHRA (Windward 2007c), a scenario was also developed to represent the consumption rate for tribal children using the Tulalip data for EW.

An additional tribal scenario is also evaluated in this HHRA based on Suquamish seafood consumption survey data (Suquamish Tribe 2000), as per requests from both Tribes and consistent with the LDW HHRA and as suggested by the Region 10 tribal framework (EPA 2007b). This scenario is described as a high end exposure scenario to characterize a range of tribal consumption rates, and it represents an upper bound on risk from seafood consumption for EW.

As was done in the LDW HHRA (Windward 2007c), risk estimates for the Suquamish scenario will be presented as quantitative estimates and discussed in the risk characterization section of the risk assessment. The Suquamish Tribe believes that the children's consumption rates presented in the Suquamish survey are valid and relevant to children of the Suquamish Tribe. For consistency with the LDW HHRA (Windward 2007c), the tribe agrees that estimates of risk to Suquamish children be included in the uncertainty section of the risk assessment.

The following five scenarios were developed for the EW: adult tribal scenarios (RME and CT) based on Tulalip data, child tribal scenarios (RME and CT) based on Tulalip data, and an adult tribal scenario based on Suquamish data, as summarized in Sections 3.3.1.1 and 3.3.1.2. A review and interpretation by EPA of the two tribal consumption studies provides the basis for the tribal scenarios presented here (EPA 2007b) (Hiltner 2007). These are the same five tribal scenarios that were evaluated in the LDW HHRA. The selection of consumption scenarios for evaluation in the EW HHRA does not set a precedent for other sites and consultation between EPA and the tribes will be necessary to select rates for other sites.

A seafood consumption survey prepared for the King County Water Quality Assessment (King County 1999) verified that fish and crab were being harvested within and near the EW by the public. Specifically, seafood harvesting was reported to have occurred from the Spokane Street Bridge and Jack Perry Memorial Park. The Spokane Street Bridge location was identified as the third most popular location for seafood harvest of the Elliott Bay and LDW locations included in the survey. Crabs were collected by more people than any other species. The number of individuals who collected sole was a third of the number of individuals who collected crabs. The King County survey also documented that a substantial fraction of Duwamish/Elliott Bay anglers are of API descent. Guidance for the development of API consumption scenarios (RME and CT) based on a King County survey (EPA 1999a) was also provided by EPA (Kissinger 2005), and details on these scenarios are presented on Section 3.3.1.3.

Finally, to provide risk information for the general public and risk information on individual resource types, a scenario for fishing that considered the consumption of a single meal per month of pelagic fish, benthic fish, crabs, and clams was developed (Section 3.3.1.4). This approach is not based on any specific fish consumption survey and is instead intended to provide additional information for less frequent (i.e., one meal per month) seafood consumers on a resource-by-resource basis. It can also be readily scaled to individual consumption rates.

This section provides a summary of the CDI calculation for COPCs for the ingestion of seafood as well as details on the exposure parameters used to evaluate each seafood consumption scenario. The CDI for COPCs from the ingestion of seafood is calculated as:

$$CDI_o = \frac{EPC \times IR \times FI \times EF \times ED \times CF}{BW \times AT} \quad \text{Equation 3-1}$$

Where:

- CDI_o = chronic daily intake from oral exposure route (mg/kg-day)
- EPC = chemical-specific exposure point concentration (mg/kg)
- IR = seafood ingestion rate (g/day)
- FI = fractional intake of media derived from contaminated source (unitless)
- EF = exposure frequency (days per year)
- ED = exposure duration (years)
- CF = conversion factor (kg/g)
- BW = body weight (kg)
- AT = averaging time (days), equivalent to the ED for non-carcinogenic COPCs and 70 years for carcinogenic COPCs

Table 3-3 presents a summary of the key scenario-specific parameters used to calculate the CDI for seafood ingestion. The seafood ingestion rates in this table are mostly the same as those that were used for the LDW HHRA (Windward 2007c), with the exception of the rates for crab and other shellfish for scenarios derived from the Tulalip Tribes study, which consist of adult tribal RME (Tulalip data), adult tribal CT (Tulalip data), child tribal RME (Tulalip data), and child tribal CT (Tulalip data). Ingestion rates for these scenarios were changed slightly by EPA following the completion of the LDW HHRA (EPA 2009a). Tables 3-4 through 3-11 provide all the exposure parameters for each scenario, including the consumption of geoduck for the tribal scenarios.

Consumption of geoduck was not included in the LDW HHRA because that species is not found in the LDW site (Windward 2007c). Other exposure parameters, such as exposure duration and body weight, are the same as those used for the LDW HHRA (Windward 2007c). Detailed explanations of the scenarios and their development are provided in Sections 3.3.1.1 through 3.3.1.4. For all seafood consumption scenarios, the exposure unit is assumed to be the entire EW study area (i.e. the scenarios will include fish and shellfish caught or collected throughout the EW study area).

Table 3-3. Summary of seafood ingestion scenarios

Scenario	Ingestion Rate (IR) (g/day)					Exposure Duration (years)	Location of Scenario-Specific Details
	Pelagic Fish	Benthic Fish	Crab	Other Shellfish	Total		
Adult tribal RME (Tulalip data)	8.1	7.5	34.4	47.5	97.5	70	Table 3-4
Adult tribal CT (Tulalip data)	1.3	1.2	5.3	7.2	15.0	30	Table 3-5
Child tribal RME (Tulalip data)	3.2	3.0	13.7	19.0	39.0 ^a	6	Table 3-6
Child tribal CT (Tulalip data)	0.52	0.48	2.1	2.9	6.0	6	Table 3-7
Adult tribal (Suquamish data)	56	29.1	49.8	448.5	583.5 ^a	70	Table 3-8
Adult API – RME	4.9	2.4	10.6	33.7	51.6	30	Table 3-9
Adult API – CT	0.5	0.24	1.1	3.5	5.3	9	Table 3-10
Adult one meal per month ^c	7.5	7.5	7.5	7.5	na	30	Table 3-11

^a As the result of rounding, the total ingestion rate is equal to 0.1 g greater than the sum of the ingestion rates for the seafood categories.

^b Adult one-meal-per-month consumption was evaluated by individual seafood categories independently to reflect different fishing and consumption practices.

API – Asian and Pacific Islander

na – not applicable

CT – central tendency

RME – reasonable maximum exposure

IR – ingestion rate

Table 3-4. Daily intake calculations – seafood ingestion, adult tribal RME scenario based on Tulalip data

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Fish and shellfish tissue Exposure route: Ingestion Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = [(EPC-p × IR-p) + (EPC-r × IR-r) + (EPC-b × IR-b) + (EPC-bwb × IR-bwb) + (EPC-c × IR-c) + (EPC-cwb × IR-cwb) + (EPC-m × IR-m) + (EPC-cl × IR-cl) + (EPC-g × IR-g) + (EPC-gwb × IR-gwb)] × FI × EF × ED-a × CF × 1/BW-a × 1/AT				
Parameter Code	Parameter Definition	Units	Value	Rationale/Reference
EPC-p	exposure point concentration in pelagic fish, perch	mg/kg ww	TBD	Section 3.3.4
EPC-r	exposure point concentration in pelagic fish, rockfish	mg/kg ww	TBD	Section 3.3.4
EPC-b	exposure point concentration in benthic fish, fillet	mg/kg ww	TBD	Section 3.3.4
EPC-bwb	exposure point concentration in benthic fish, whole body	mg/kg ww	TBD	Section 3.3.4
EPC-c	exposure point concentration in crabs, edible meat	mg/kg ww	TBD	Section 3.3.4
EPC-cwb	exposure point concentration in crabs, whole body	mg/kg ww	TBD	Section 3.3.4
EPC-m	exposure point concentration in mussels	mg/kg ww	TBD	Section 3.3.4
EPC-cl	exposure point concentration in clams	mg/kg ww	TBD	Section 3.3.4
EPC-g	exposure point concentration in geoduck, edible meat	mg/kg ww	TBD	Section 3.3.4
EPC-gwb	exposure point concentration in geoduck, whole body	mg/kg ww	TBD	Section 3.3.4
IR-p	ingestion rate – pelagic fish, perch	g/day	7.1	Section 3.3.1.1
IR-r	ingestion rate – pelagic fish, rockfish	g/day	1.0	Section 3.3.1.1
IR-b	ingestion rate – benthic fish	g/day	7.5	Section 3.3.1.1
IR-bwb	ingestion rate – benthic fish, whole body	g/day	0	Section 3.3.1.1
IR-c	ingestion rate – crabs, edible meat	g/day	26.1	Section 3.3.1.1
IR-cwb	ingestion rate – crabs, whole body	g/day	8.3	Section 3.3.1.1
IR-m	ingestion rate – mussels	g/day	0.8	Section 3.3.1.1
IR-cl	ingestion rate – clams	g/day	39.3	Section 3.3.1.1
IR-g	ingestion rate – geoduck, edible meat	g/day	6.5	Section 3.3.1.1
IR-gwb	ingestion rate – geoduck, whole body	g/day	0.9	Section 3.3.1.1
FI	fractional intake derived from source	unitless	1 ^a	EPA (2007b)
EF	exposure frequency	days/yr	365 ^b	EPA (1991)
ED-a	exposure duration – adult	Years	70	EPA (2005a)
CF	conversion factor	kg/g	0.001	na
BW-a	body weight-adult	Kg	81.8	Toy et al. (1996)
AT-C	averaging time – cancer	Days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	Days	25,550	EPA (1989)

Source: Standard Table 4 in EPA (1998)

^a A fractional intake derived from source of 1 was directed by EPA (2007b).

^b Default exposure frequency of 350 days/yr modified to 365 days/yr to account for the fact that seafood consumption rate estimates are based on 365 days/yr.

EPA – US Environmental Protection Agency

TBD – to be determined

na – not applicable

ww – wet weight

RME – reasonable maximum exposure

Table 3-5. Daily intake calculations – seafood ingestion, adult tribal CT scenario based on Tulalip data

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Fish and shellfish tissue Exposure route: Ingestion Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = [(EPC-p × IR-p) + (EPC-r × IR-r) + (EPC-b × IR-b) + (EPC-bwb × IR-bwb) + (EPC-c × IR-c) + (EPC-cwb × IR-cwb) + (EPC-m × IR-m) + ((EPC-cl × IR-cl) + (EPC-g × IR-g) + (EPC-gwb × IR-gwb))] × FI × EF × ED-a × CF × 1/BW-a × 1/AT				
Parameter	Parameter Definition	Units	Value	Rationale/
EPC-p	exposure point concentration in pelagic fish, perch	mg/kg ww	TBD ^a	Section 3.3.4
EPC-r	Exposure point concentration in pelagic fish, rockfish	mg/kg ww	TBD ^a	Section 3.3.4
EPC-b	exposure point concentration in benthic fish, fillet	mg/kg ww	TBD ^a	Section 3.3.4
EPC-bwb	exposure point concentration in benthic fish, whole	mg/kg ww	TBD ^a	Section 3.3.4
EPC-c	exposure point concentration in crabs, edible meat	mg/kg ww	TBD ^a	Section 3.3.4
EPC-cwb	exposure point concentration in crabs, whole body	mg/kg ww	TBD ^a	Section 3.3.4
EPC-m	exposure point concentration in mussels	mg/kg ww	TBD ^a	Section 3.3.4
EPC-cl	exposure point concentration in clams	mg/kg ww	TBD	Section 3.3.4
EPC-g	exposure point concentration in geoduck, edible meat	mg/kg ww	TBD ^a	Section 3.3.4
EPC-gwb	exposure point concentration in geoduck, whole body	mg/kg ww	TBD ^a	Section 3.3.4
IR-p	ingestion rate – pelagic fish, perch	g/day	1.1	Section 3.3.1.1
IR-r	ingestion rate – pelagic fish, rockfish	g/day	0.2	Section 3.3.1.1
IR-b	ingestion rate – benthic fish	g/day	1.2	Section 3.3.1.1
IR-bwb	ingestion rate – benthic fish, whole body	g/day	0	Section 3.3.1.1
IR-c	ingestion rate – crabs, edible meat	g/day	4.0	Section 3.3.1.1
IR-cwb	ingestion rate – crabs, whole body	g/day	1.3	Section 3.3.1.1
IR-m	ingestion rate – mussels	g/day	0.1	Section 3.3.1.1
IR-cl	ingestion rate – clams	g/day	6.0	Section 3.3.1.1
IR-g	ingestion rate – geoduck, edible meat	g/day	1.0	Section 3.3.1.1
IR-gwb	ingestion rate – geoduck, whole body	g/day	0.1	Section 3.3.1.1
FI	fractional intake derived from source	Unitless	1 ^b	EPA (2007b)
EF	exposure frequency	days/yr	365 ^c	EPA (1991)
ED-a	exposure duration – adult	Years	30	EPA (EPA 1997)
CF	conversion factor	kg/g	0.001	na
BW-a	body weight – adult	Kg	81.8	Toy et al. (1996)
AT-C	averaging time – cancer	Days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	Days	10,950	EPA (1989)

Source: Standard Table 4 in EPA (1998)

^a EPCs for CT scenarios are based on mean concentrations, in contrast to the EPCs for the RME scenarios, which are based on 95% UCLs on mean concentrations.

^b A fractional intake derived from source of 1 was directed by EPA (2007b).

^c Default exposure frequency of 350 days/yr modified to 365 days/yr to account for the fact that seafood consumption rate estimates are based on 365 days/yr.

CT – central tendency

TBD – to be determined

EPA – US Environmental Protection Agency

UCL – upper confidence limit on the mean

na – not applicable

ww – wet weight

RME – reasonable maximum exposure

Table 3-6. Daily intake calculations – seafood ingestion, child tribal RME scenario based on Tulalip data

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Fish and shellfish tissue Exposure route: Ingestion Intake equation/model name: Chronic Daily Intake (CDI) (mg/kg-day) = [(EPC-p × IR-p) + (EPC-r × IR-r) + (EPC-b × IR-b) + (EPC-bwb × IR-bwb) + (EPC-c × IR-c) + (EPC-cwb × IR-cwb) + (EPC-m × IR-m) + (EPC-cl × IR-cl) + (EPC-g × IR-g) + (EPC-gwb × IR-gwb)] × FI × EF × ED-a × CF × 1/BW-ct × 1/AT				
Parameter Code	Parameter Definition	Units	Value	Rationale/Reference
EPC-p	exposure point concentration in pelagic fish, perch	mg/kg ww	TBD	Section 3.3.4
EPC-r	exposure point concentration in pelagic fish, rockfish	mg/kg ww	TBD	Section 3.3.4
EPC-b	exposure point concentration in benthic fish, fillet	mg/kg ww	TBD	Section 3.3.4
EPC-bwb	exposure point concentration in benthic fish, whole body	mg/kg ww	TBD	Section 3.3.4
EPC-c	exposure point concentration in crabs, edible meat	mg/kg ww	TBD	Section 3.3.4
EPC-cwb	exposure point concentration in crabs, whole body	mg/kg ww	TBD	Section 3.3.4
EPC-m	exposure point concentration in mussels	mg/kg ww	TBD	Section 3.3.4
EPC-cl	exposure point concentration in clams	mg/kg ww	TBD	Section 3.3.4
EPC-g	exposure point concentration in geoduck, edible meat	mg/kg ww	TBD	Section 3.3.4
EPC-gwb	exposure point concentration in geoduck, whole body	mg/kg ww	TBD	Section 3.3.4
IR-p	ingestion rate – pelagic fish, perch	g/day	2.8	Section 3.3.1.2
IR-r	ingestion rate – pelagic fish, rockfish	g/day	0.4	Section 3.3.1.2
IR-b	ingestion rate – benthic fish	g/day	3.0	Section 3.3.1.2
IR-bwb	ingestion rate – benthic fish, whole body	g/day	0	Section 3.3.1.2
IR-c	ingestion rate – crabs, edible meat	g/day	10.4	Section 3.3.1.2
IR-cwb	ingestion rate – crabs, whole body	g/day	3.3	Section 3.3.1.2
IR-m	ingestion rate – mussels	g/day	0.3	Section 3.3.1.2
IR-cl	ingestion rate – clams	g/day	15.7	Section 3.3.1.2
IR-g	ingestion rate – geoduck, edible meat	g/day	2.6	Section 3.3.1.2
IR-gwb	ingestion rate – geoduck, whole body	g/day	0.4	Section 3.3.1.2
FI	fractional intake derived from source	unitless	1 ^b	EPA (2007b)
EF	exposure frequency	days/yr	365 ^a	EPA (1991)
ED-c	exposure duration – child	years	6	EPA (1991)
CF	conversion factor	kg/g	0.001	na
BW-ct	body weight – child Tulalip	kg	15.2	Toy et al. (1996)
AT-C	averaging time – cancer	days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	days	2,190	EPA (1989)

Source: Standard Table 4 in EPA (1998)

^a Default exposure frequency of 350 days/yr modified to 365 days/yr to account for the fact that seafood consumption rate estimates are based on 365 days/yr.

^b A fractional intake derived from source of 1 was directed by EPA (2007b).

EPA – US Environmental Protection Agency

RME – reasonable maximum exposure

na – not applicable

ww – wet weight

Table 3-7. Daily intake calculations – seafood ingestion, child tribal CT scenario based on Tulalip data

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Fish and shellfish tissue Exposure route: Ingestion Intake equation/model name: Chronic Daily Intake (CDI) (mg/kg-day) = [(EPC-p × IR-p) + (EPC-r × IR-r) + (EPC-b × IR-b) + (EPC-bwb × IR-bwb) + (EPC-c × IR-c) + (EPC-cwb × IR-cwb) + (EPC-m × IR-m) + (EPC-cl × IR-cl) + (EPC-g × IR-g) + (EPC-gwb × IR-gwb)] × FI × EF × ED-a × CF × 1/BW-ct × 1/AT				
Parameter Code	Parameter Definition	Units	Value	Rationale/Reference
EPC-p	exposure point concentration in pelagic fish, perch	mg/kg ww	TBD ^a	Section 3.3.4
EPC-r	exposure point concentration in pelagic fish, rockfish	mg/kg ww	TBD ^a	Section 3.3.4
EPC-b	exposure point concentration in benthic fish, fillet	mg/kg ww	TBD ^a	Section 3.3.4
EPC-bwb	exposure point concentration in benthic fish, whole body	mg/kg ww	TBD ^a	Section 3.3.4
EPC-c	exposure point concentration in crabs, edible meat	mg/kg ww	TBD ^a	Section 3.3.4
EPC-cwb	exposure point concentration in crabs, whole body	mg/kg ww	TBD ^a	Section 3.3.4
EPC-m	exposure point concentration in mussels	mg/kg ww	TBD ^a	Section 3.3.4
EPC-cl	exposure point concentration in clams	mg/kg ww	TBD	Section 3.3.4
EPC-g	exposure point concentration in geoduck, edible meat	mg/kg ww	TBD ^a	Section 3.3.4
EPC-gwb	exposure point concentration in geoduck, whole body	mg/kg ww	TBD ^a	Section 3.3.4
IR-p	ingestion rate – pelagic fish, perch	g/day	0.44	Section 3.3.1.2
IR-r	ingestion rate – pelagic fish, rockfish	g/day	0.08	Section 3.3.1.2
IR-b	ingestion rate – benthic fish	g/day	0.48	Section 3.3.1.2
IR-bwb	ingestion rate – benthic fish, whole body	g/day	0	Section 3.3.1.2
IR-c	ingestion rate – crabs, edible meat	g/day	1.6	Section 3.3.1.2
IR-cwb	ingestion rate – crabs, whole body	g/day	0.5	Section 3.3.1.2
IR-m	ingestion rate – mussels	g/day	0.04	Section 3.3.1.2
IR-cl	ingestion rate – clams	g/day	2.4	Section 3.3.1.2
IR-g	ingestion rate – geoduck, edible meat	g/day	0.4	Section 3.3.1.2
IR-gwb	ingestion rate – geoduck, whole body	g/day	0.04	Section 3.3.1.2
FI	fractional intake derived from source	unitless	1 ^b	EPA (2007b) ^b
EF	exposure frequency	days/yr	365 ^c	EPA (1991)
ED-c	exposure duration – child	years	6	EPA (1991)
CF	conversion factor	kg/g	0.001	na
BW-ct	body weight – child Tulalip	kg	15.2	Toy et al. (1996)
AT-C	averaging time – cancer	days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	days	2,190	EPA (1989)

Source: Standard Table 4 in EPA (1998)

^a EPCs for CT scenarios are based on mean concentrations, in contrast to the EPCs for the RME scenarios, which are based on 95% UCLs on mean concentrations.

^b A fractional intake derived from source of 1 was directed by EPA (2007b).

^c Default exposure frequency of 350 days/yr modified to 365 days/yr to account for the fact that seafood consumption rate estimates are based on 365 days/yr.

CT – central tendency

EPA – US Environmental Protection Agency

na – not applicable

TBD – to be determined

UCL – upper confidence limit on the mean

ww – wet weight

Table 3-8. Daily intake calculations – seafood ingestion, adult tribal scenario based on Suquamish data

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Fish and shellfish tissue Exposure route: Ingestion Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = [(EPC-p × IR-p) + (EPC-r × IR-r) + (EPC-b × IR-b) + (EPC-bwb × IR-bwb) + (EPC-c × IR-c) + (EPC-cwb × IR-cwb) + (EPC-m × IR-m) + (EPC-cl × IR-cl) + (EPC-g × IR-g) + (EPC-gwb × IR-gwb)] × FI × EF × ED-a × CF × 1/BW-a × 1/AT				
Parameter Code	Parameter Definition	Units	Value	Rationale/Reference
EPC-p	exposure point concentration in pelagic fish, perch	mg/kg ww	TBD	Section 3.3.4
EPC-r	exposure point concentration in pelagic fish, rockfish	mg/kg ww	TBD	Section 3.3.4
EPC-b	exposure point concentration in benthic fish, fillet	mg/kg ww	TBD	Section 3.3.4
EPC-bwb	exposure point concentration in benthic fish, whole body	mg/kg ww	TBD	Section 3.3.4
EPC-c	exposure point concentration in crabs, edible meat	mg/kg ww	TBD	Section 3.3.4
EPC-cwb	exposure point concentration in crabs, whole body	mg/kg ww	TBD	Section 3.3.4
EPC-m	exposure point concentration in mussels	mg/kg ww	TBD	Section 3.3.4
EPC-cl	exposure point concentration in clams	mg/kg ww	TBD	Section 3.3.4
EPC-g	exposure point concentration in geoduck, edible meat	mg/kg ww	TBD	Section 3.3.4
EPC-gwb	exposure point concentration in geoduck, whole body	mg/kg ww	TBD	Section 3.3.4
IR-p	ingestion rate – pelagic fish, perch	g/day	0.6	Section 3.3.1.1
IR-r	ingestion rate – pelagic fish, rockfish	g/day	55.4	Section 3.3.1.1
IR-b	ingestion rate – benthic fish	g/day	25.9	Section 3.3.1.1
IR-bwb	ingestion rate – benthic fish, whole body	g/day	3.2	Section 3.3.1.1
IR-c	ingestion rate – crabs, edible meat	g/day	37.8	Section 3.3.1.1
IR-cwb	ingestion rate – crabs, whole body	g/day	12.0	Section 3.3.1.1
IR-m	ingestion rate – mussels	g/day	5.0	Section 3.3.1.1
IR-cl	ingestion rate –clams	g/day	393.7	Section 3.3.1.1
IR-g	ingestion rate – geoduck, edible meat	g/day	43.8	Section 3.3.1.1
IR-gwb	ingestion rate – geoduck, whole body	g/day	6.0	Section 3.3.1.1
FI	fractional intake derived from source	unitless	1 ^b	EPA (2007b)
EF	exposure frequency	days/yr	365 ^a	EPA (1991)
ED-a	exposure duration – adult	years	70	EPA (2005a)
CF	conversion factor	kg/g	0.001	na
BW-a	body weight – adult	kg	79 ^c	Suquamish Tribe (2000)
AT-C	averaging time – cancer	days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	days	25,550	EPA (1989)

Source: Standard Table 4 in EPA (1998)

^a Default exposure frequency of 350 days/yr modified to 365 days/yr to account for the fact that seafood consumption rate estimates are based on 365 days/yr.

^b A fractional intake derived from source of 1 was directed by EPA (2007b).

^c Average body weight based on information provided by the Suquamish Tribe.

EPA – US Environmental Protection Agency

TBD – to be determined

na – not applicable

ww – wet weight

Table 3-9. Daily intake calculations – seafood ingestion, adult API RME scenario

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Fish and shellfish tissue Exposure route: Ingestion Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = [(EPC-p × IR-p) + (EPC-r × IR-r) + (EPC-b × IR-b) + (EPC-bwb × IR-bwb) + (EPC-c × IR-c) + (EPC-cwb × IR-cwb) + (EPC-m × IR-m) + (EPC-cl × IR-cl) +] × FI × EF × ED-a × CF × 1/BW-a × 1/AT				
Parameter Code	Parameter Definition	Units	Value	Rationale/Reference
EPC-p	exposure point concentration in pelagic fish, perch	mg/kg ww	TBD	Section 3.3.4
EPC-r	exposure point concentration in pelagic fish, rockfish	mg/kg ww	TBD	Section 3.3.4
EPC-b	exposure point concentration in benthic fish, fillet	mg/kg ww	TBD	Section 3.3.4
EPC-bwb	exposure point concentration in benthic fish, whole body	mg/kg ww	TBD	Section 3.3.4
EPC-c	exposure point concentration in crabs, edible meat	mg/kg ww	TBD	Section 3.3.4
EPC-cwb	exposure point concentration in crabs, whole body	mg/kg ww	TBD	Section 3.3.4
EPC-m	exposure point concentration in mussels	mg/kg ww	TBD	Section 3.3.4
EPC-cl	exposure point concentration in clams	mg/kg ww	TBD	Section 3.3.4
IR-p	ingestion rate – pelagic fish, perch	g/day	0.5	Section 3.3.1.3
IR-r	ingestion rate – pelagic fish, rockfish	g/day	4.4	Section 3.3.1.3
IR-b	ingestion rate – benthic fish	g/day	2.0	Section 3.3.1.3
IR-bwb	ingestion rate – benthic fish, whole body	g/day	0.4	Section 3.3.1.3
IR-c	ingestion rate – crabs, edible meat	g/day	5.7	Section 3.3.1.3
IR-cwb	ingestion rate – crabs, whole body	g/day	4.9	Section 3.3.1.3
IR-m	ingestion rate – mussels	g/day	4.6	Section 3.3.1.3
IR-cl	ingestion rate – clams	g/day	29.1	Section 3.3.1.3
FI	fractional intake derived from source	unitless	1	Kissinger (2005)
EF	exposure frequency	days/yr	365 ^b	EPA (1991)
ED-a	exposure duration – adult	years	30	EPA (1989)
CF	conversion factor	kg/g	0.001	na
BW-a	body weight – adult	kg	63 ^c	EPA (1999a)
AT-C	averaging time – cancer	days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	days	10,950	EPA (1989)

Source: Standard Table 4 in EPA (1998)

^a A fractional intake derived from source of 1 was directed by EPA (Kissinger 2005).

^b Default exposure frequency of 350 days/yr modified to 365 days/yr to account for the fact that seafood consumption rate estimates are based on 365 days/yr.

^c Average body weight for all surveyed individuals in API seafood consumption study in King County, as reported in EPA (1999a).

API – Asian and Pacific Islander

EPA – US Environmental Protection Agency

na – not applicable

RME – reasonable maximum exposure

TBD – to be determined

ww – wet weight

Table 3-10. Daily intake calculations – seafood ingestion, adult API CT scenario

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Fish and shellfish tissue Exposure route: Ingestion Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = [(EPC-p × IR-p) + (EPC-r × IR-r) + (EPC-b × IR-b) + (EPC-bwb × IR-bwb) + (EPC-c × IR-c) + (EPC-cwb × IR-cwb) + (EPC-m × IR-m) + (EPC-cl × IR-cl)] × FI × EF × ED-a × CF × 1/BW-a × 1/AT				
Parameter Code	Parameter Definition	Units	Value	Rationale/Reference
EPC-p	exposure point concentration in pelagic fish, perch	mg/kg ww	TBD ^a	Section 3.3.4
EPC-p	exposure point concentration in pelagic fish, rockfish	mg/kg ww	TBD ^a	Section 3.3.4
EPC-b	exposure point concentration in benthic fish, fillet	mg/kg ww	TBD ^a	Section 3.3.4
EPC-bwb	exposure point concentration in benthic fish, whole body	mg/kg ww	TBD ^a	Section 3.3.4
EPC-c	exposure point concentration in crabs, edible meat	mg/kg ww	TBD ^a	Section 3.3.4
EPC-cwb	exposure point concentration in crabs, whole body	mg/kg ww	TBD ^a	Section 3.3.4
EPC-m	exposure point concentration in mussels	mg/kg ww	TBD ^a	Section 3.3.4
EPC-cl	exposure point concentration in clams	mg/kg ww	TBD	Section 3.3.4
IR-p	ingestion rate – pelagic fish, perch	g/day	0.05	Section 3.3.1.3
IR-r	ingestion rate – pelagic fish, rockfish	g/day	0.45	Section 3.3.1.3
IR-b	ingestion rate – benthic fish	g/day	0.2	Section 3.3.1.3
IR-bwb	ingestion rate – benthic fish, whole body	g/day	0.04	Section 3.3.1.3
IR-c	ingestion rate – crabs, edible meat	g/day	0.6	Section 3.3.1.3
IR-cwb	ingestion rate – crabs, whole body	g/day	0.5	Section 3.3.1.3
IR-m	ingestion rate – mussels	g/day	0.5	Section 3.3.1.3
IR-cl	ingestion rate – clams	g/day	3.0	Section 3.3.1.3
FI	fractional intake derived from source	Unitless	1 ^b	Kissinger (2005)
EF	exposure frequency	days/yr	365 ^c	EPA (1991)
ED-a	exposure duration – adult	Years	9	EPA (1989)
CF	conversion factor	kg/g	0.001	na
BW-a	body weight – adult	Kg	63 ^d	EPA (1999a)
AT-C	averaging time – cancer	Days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	Days	3,285	EPA (1989)

Source: Standard Table 4 in EPA (1998)

^a EPCs for CT scenarios are based on mean concentrations, in contrast to the EPCs for the RME scenarios, which are based on 95% UCLs on mean concentrations.

^b A fractional intake derived from source of 1 was directed by EPA (Kissinger 2005).

^c Default exposure frequency of 350 days/yr modified to 365 days/yr to account for the fact that seafood consumption rate estimates are based on 365 days/yr.

^d Average body weight for all surveyed individuals in API seafood consumption study in King County, as reported in EPA (1999a).

API – Asian and Pacific Islander

CT – central tendency

EPA – US Environmental Protection Agency

na – not applicable

TBD – to be determined

UCL – upper confidence limit on the mean

ww – wet weight

Table 3-11. Daily intake calculations – seafood ingestion, adult one-meal-per-month scenario

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Fish and shellfish tissue Exposure route: Ingestion Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = [(EPC-p × IR-p) or (EPC-b × IR-b) or (EPC-c × IR-c) or (EPC-cl × IR-cl)] × FI × EF × ED-a × CF × 1/BW-a × 1/AT				
Parameter Code	Parameter Definition	Units	Value	Rationale/Reference
EPC-p	exposure point concentration in pelagic fish ^a	mg/kg ww	TBD	Section 3.3.4
EPC-b	exposure point concentration in benthic fish, fillet	mg/kg ww	TBD	Section 3.3.4
EPC-c	exposure point concentration in crabs, edible meat	mg/kg ww	TBD	Section 3.3.4
EPC-cl	exposure point concentration in intertidal clams	mg/kg ww	TBD	Section 3.3.4
IR-p	ingestion rate – pelagic fish	g/day	7.5 ^b	Section 3.3.1.4
IR-b	ingestion rate – benthic fish	g/day	7.5 ^b	Section 3.3.1.4
IR-c	ingestion rate – crabs, edible meat	g/day	7.5 ^b	Section 3.3.1.4
IR-cl	ingestion rate – clams	g/day	7.5 ^b	Section 3.3.1.4
FI	fractional intake derived from source	unitless	1	na
EF	exposure frequency	days/yr	365 ^c	EPA (1991)
ED-a	exposure duration – adult	years	30	EPA (1989)
CF	conversion factor	kg/g	0.001	na
BW-a	body weight – adult	kg	71.8	EPA (1997)
AT-C	averaging time – cancer	days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	days	10,950	EPA (1989)

Source: Standard Table 4 in EPA (1998)

- ^a The adult one-meal-per-month pelagic fish consumption scenario will be evaluated using both perch and rockfish
- ^b Adult one-meal-per-month consumption was evaluated by individual seafood categories independently to provide information to the public and risk managers on consumption of various potential types of fish and shellfish. Risks from adult one-meal-per-month consumption are divided into four scenarios that address risks individually for each of the four main seafood consumption categories (i.e., benthic fish, pelagic fish, clams, and crabs). Each scenario assumes that one 227 gram (8 oz.) meal is consumed per month, which equates to 7.5 g/day. Consumption of anadromous fish (e.g., salmon) is not considered based on the EPA recommendation that the site-related concentration term for salmon is zero for bioaccumulative contaminants (EPA 2005a).
- ^c Default exposure frequency of 350 days/yr modified to 365 days/yr to account for the fact that seafood consumption rate estimates are based on 365 days/yr.

EPA – US Environmental Protection Agency

na – not applicable

TBD – to be determined

ww – wet weight

3.3.1.1 Adult tribal seafood consumption scenarios based on Tulalip and Suquamish data

The consumption rates in the tribal framework guidance (EPA 2007b) are based on seafood consumption surveys of the Tulalip Tribes (Toy et al. 1996) and the Suquamish Tribe (Suquamish Tribe 2000). Briefly, the 95th percentile of total seafood consumption from Puget Sound was attributed to different seafood categories (anadromous, bottom feeding, and pelagic fish, as well as shellfish) assuming the proportion of consumption in each category calculated for average consumption (including both consumers and non-consumers)⁵ also applied to the 95th percentile consumption of Puget Sound seafood. For example, the average consumption of anadromous fish divided by the sum of the averages of consumption of all seafood categories was 49.7%. Thus, it was assumed that 49.7% of the 95th percentile of total seafood consumed from Puget Sound by Tulalip Tribal members (194 g/day) was anadromous fish (96.4 g/day) (EPA 2007b). The same approach was applied for estimating the consumption of different seafood categories for the adult Tulalip CT scenario using the 50th percentile of total seafood consumed from Puget Sound (Hiltner 2007). Total quantities of non-anadromous seafood consumed for the tribal adult scenario based on Tulalip data were 97.5 g/day and 15 g/day for the RME and CT scenarios, respectively. Total non-anadromous seafood consumed for the tribal adult scenario based on Suquamish data was 583.5 g/day.

Table 3-12 presents the tribal seafood consumption rates for different components of the market basket. The last column discusses the presence and prevalence of each seafood group in the EW. As agreed upon with EPA, consumption of anadromous fish was not included for EW tribal exposure and risk estimates (EPA 2005a) because the bulk of the body burden of bioaccumulative contaminants in adult salmon is not obtained from the EW. Because the site-related contaminant body burden is low, most risks associated with salmon consumption were deemed not to be site-related.

Table 3-12. Seafood species consumed by Tulalip and Suquamish adults and EW species used to represent consumed species

Seafood Category	Members	Grams per Day			Rationale for Inclusion/Exclusion and Representative Species Present in the EW
		Adult Tulalip RME ^a	Adult Tulalip CT ^b	Adult Suquamish ^c	
Anadromous fish	Salmon	96.4	14.9	183.5	Consumption rate will not be used in this HHRA. Although adult salmon are common in EW, they are not included in the EW HHRA because of their migratory behavior.

⁵ In calculating the average consumption for each category, consumption for a given category for people who did not consume that particular seafood type (i.e. non-consumers of a given category) was equal to zero.

Seafood Category	Members	Grams per Day			Rationale for Inclusion/Exclusion and Representative Species Present in the EW
		Adult Tulalip RME ^a	Adult Tulalip CT ^b	Adult Suquamish ^c	
Pelagic fish	including cod, perch, and rockfish	8.1	1.3	56	Perch and rockfish are common in the EW.
Benthic/demersal fish	halibut, sole, snappers	7.5	1.2	29.1	English sole are common in the EW.
Shellfish	bivalves, snails, shrimp, crabs	81.9	12.5	498.4	Marine shellfish species (crabs, clams, and mussels) are present in the EW. Only one shrimp sample was collected in the 2008 sampling effort because shrimp were not commonly found.

^a From Table B-1 of EPA (2007b), 95th percentile of the total seafood consumption rate from Puget Sound = 194 g/day.

^b Provided by EPA (Hiltner 2007); 50th percentile of total seafood consumption rate from Puget Sound = 29.9 g/day.

^c From Table B-2 of EPA (2007b); 95th percentile of the total seafood consumption rate from Puget Sound = 766.8 g/day.

CT – central tendency

EPA – US Environmental Protection Agency

HHRA – human health risk assessment

EW –East Waterway

RME – reasonable maximum exposure

The consumption of different types of shellfish within the shellfish seafood category for the adult tribal RME scenario based on Tulalip data and the adult tribal scenario based on Suquamish data was specified by EPA in the application of their framework to the LDW (EPA 2005a). The same approach will be applied for the EW. The species-specific information will be used together with concentration data for that species (where available) in the market basket estimate. The same methodology was applied to develop the adult tribal CT scenario based on Tulalip data. Briefly, average consumption rates (for consumers and non-consumers) of clams, mussels, and crabs were calculated and used by EPA to develop concentration weighting factors that could be applied to the shellfish seafood category. Using the adult tribal RME clam consumption rate based on Tulalip data as an example, average clam consumption was 46% of the sum of averages of other shellfish consumed (clams, mussels, and crabs). This percentage was applied to the adult tribal shellfish consumption rate (81.9 g/day, 95th percentile of Puget Sound shellfish consumption) to generate a clam consumption rate of 37.7 g/day for the adult tribal RME scenario based on Tulalip data. Similar procedures were used to develop consumption rates for the adult tribal CT scenario based on Tulalip data and for the adult tribal scenario based on Suquamish data. Table 3-13 presents the concentration weighting factors (as percentages) for clams, mussels, and crabs and the calculated consumption of each of the adult tribal RME and CT scenarios based on Tulalip data and adult tribal scenario based on Suquamish data.

The shellfish consumption rate was fractionated to develop ingestion rate-weighted concentrations when data on multiple species were available for the shellfish market basket fraction. Rates for individual shellfish market basket components should not be used outside of this context. For example, if risks associated with consumption of a particular resource, such as crabs, were of interest, development of a 95th percentile consumer only crab consumption rate would be appropriate (i.e., the crab consumption rate provided here is part of a market basket representing the 95th percentile of total seafood consumption, but does not represent the 95th percentile of crab consumption).

Table 3-13. Adult tribal consumption of shellfish (crabs, clams, and mussels) based on Tulalip and Suquamish data

Shellfish Type	Percentage of Total Shellfish Consumption	RME or 95th Percentile Scenario Consumption Rate (g/day) ^a	CT Scenario Consumption Rate (g/day)
Adult Tribal RME Based on Tulalip Data^b			
Crabs	42	34.4	5.3
Clams ^c	48	39.3	6.0
Mussels	1	0.8	0.1
Geoduck ^d	9	7.4	1.1
Adult Tribal Based on Suquamish Data^e			
Crabs	10	49.8	na
Clams ^c	79	393.7	na
Mussels	1	5.0	na
Geoduck	10	49.8	na

^a The adult consumption rate is the product of the percentage of total consumption and the overall shellfish consumption rate for the Tulalip and Suquamish Tribes, as applicable. The rate based on the Tulalip Tribes study (Toy et al. 1996) is defined as the adult tribal RME scenario, consistent with the LDW HHRA. The scenario based on Suquamish data is provided for the estimation of upper-bound risks and is not designated as an RME scenario.

^b Tulalip Tribes 95th percentile total Puget Sound shellfish consumption = 81.9 g/day, consumption percentages provided to EWG by Lon Kissinger (December 12, 2008). The Tulalip Tribes CT scenario for total Puget Sound seafood consumption was based on an ingestion rate of 29.9 g/day (Hiltner 2007).

^c Includes Manila/littleneck clams, horse clams, butter clams, cockles, oysters, and scallops (EPA 2005a).

^d Geoduck consumption was not reported in the Tulalip Tribes survey (Toy et al. 1996). Therefore average geoduck consumption for the Tulalip Tribes-based scenario was assumed to occur at the average Suquamish Tribe geoduck consumption rate (Suquamish Tribe 2000) multiplied by the ratio of total Tulalip Tribes shellfish consumption divided by total Suquamish Tribe shellfish consumption.

^e Suquamish Tribe 95th percentile total Puget Sound shellfish consumption = 498.4 g/day; consumption percentages from Table B-2 of EPA (2007b).

CT – central tendency

EPA – US Environmental Protection Agency

na – not applicable

RME – reasonable maximum exposure

An approach similar to the apportionment of total shellfish consumption was used for apportionment of the pelagic fish consumption into perch and rockfish categories. This apportionment is illustrated in Table 3-14. The Tulalip Tribes consumption study provided information about rockfish and perch consumption as part of the pelagic fish category in that study (Toy et al. 1996). Average consumption rates (for consumers and non-consumers) of perch and rockfish were calculated and used to develop concentration weighting factors that could be applied to the shellfish seafood category. In the Suquamish Tribe study, rockfish were included as part of the benthic fish category (Suquamish Tribe 2000). Perch were a part of the pelagic category in the Suquamish study but were only eaten by two respondents. Rockfish are considered to be pelagic in their lifestyle as discussed in the ecological risk assessment technical memorandum for the EW (Windward 2009). For the adult tribal scenario based on Suquamish data, total reported pelagic fish consumption was allocated between perch and rockfish using percentages based on average perch consumption relative to average rockfish consumption, as shown in Table 3-14.

Table 3-14. Adult tribal consumption of pelagic fish (perch and rockfish) based on Tulalip and Suquamish data

Fish Type	Percentage of Total Pelagic Consumption	RME or 95th Percentile Scenario Consumption Rate (g/day)^a	CT Scenario Consumption Rate (g/day)
Adult Tribal RME Based on Tulalip Data^b			
Perch	88	7.1	1.1
Rockfish	12	1	0.2
Adult Tribal Based on Suquamish Data^c			
Perch	1	0.6	na
Rockfish	99	55.4	na

^a The adult consumption rate is the product of the percentage of total consumption and the overall pelagic fish consumption rate for the Tulalip and Suquamish Tribes, as applicable. The rate based on the Tulalip Tribes study (Toy et al. 1996) is defined as the adult tribal RME scenario, consistent with the LDW HHRA. The scenario based on Suquamish data is provided for the estimation of upper-bound risks and is not designated as an RME scenario.

^b Percentage of each fish type calculated based on average perch and rockfish consumption provided by Lon Kissinger to EWG (December 12, 2008).

^c Percentage of each fish type calculated based on reported average consumption of rockfish and perch (Suquamish Tribe 2000). Note that rockfish consumption was included in the total consumption for the benthic category in the Suquamish survey, but based on the rationale provided in Section 3.1.1.1, they were considered part of the pelagic fish category for apportionment.

The EPA tribal seafood consumption framework does not provide specific guidance on the portions of seafood consumed (e.g., whole body vs. filleted fish) within a specific seafood category. Quantification of these portions allows for the refinement of risk estimates and reduction of uncertainty. For pelagic fish, clams (other than geoduck), and mussels, only whole-body data are available (whole body, including the siphon but not the shell for mussels and clams) so it was not possible to consider the different types of tissue consumed for these seafood categories. For benthic fish from the EW, both whole-body and fillet chemical concentration data are available. Similarly, for EW crab,

chemical concentration data for edible meat (i.e., muscle tissue) and estimates of whole-body chemical concentration data (based on edible meat and hepatopancreas) are also available. Geoduck consumption was also apportioned as edible meat or whole-body consumption. Geoduck whole body includes the edible meat and the gut ball portions. Information on the relative percentage of consumption of these seafood categories is available from the seafood consumptions surveys of the Tulalip Tribes (Toy et al. 1996) and the Suquamish Tribe (2000). The percentages for the tissue categories and mean consumption rates for whole-body crabs, whole-body benthic fish, and whole-body geoduck were used to calculate the consumption rates for each of the seafood tissue categories, as presented in Table 3-15.

Table 3-15. Portions of benthic fish and crab consumed – adult tribal RME and CT scenarios based on Tulalip data and adult tribal scenario based on Suquamish data

Seafood Category	Percentage of Consumption	RME Scenario or 95th Percentile Consumption Rate (g/day) ^a	CT Scenario Consumption Rate (g/day)
Adult Tribal RME Scenario Based on Tulalip Data			
Crab, edible meat	76 ^b	26.1	4.0
Crab, whole body	24 ^b	8.3	1.3
Benthic fish, fillet	100 ^c	7.5	1.2
Benthic fish, whole body	0 ^c	0	0
Geoduck, edible meat	88 ^d	6.5	1.0
Geoduck, whole body	12 ^d	0.9	0.1
Adult Tribal Scenario Based on Suquamish Data			
Crab, edible meat	76 ^d	37.8	na
Crab, whole body	24 ^d	12.0	na
Benthic fish, fillet	89 ^d	25.9	na
Benthic fish, whole body	11 ^d	3.2	na
Geoduck, edible meat	88	43.8	na
Geoduck, whole body	12	6.0	na

^a Product of percentage of consumption and the consumption rate for total crab or benthic fish, from EPA framework (EPA 2005a); see Tables 3-12 and 3-13 of this document. The rate based on the Tulalip Tribes study (Toy et al. 1996) is defined as the adult tribal RME scenario, consistent with the LDW HHRA. The scenario based on Suquamish data is provided for the estimation of upper-bound risks and is not designated as an RME scenario.

^b Portions of crab or geoduck consumed were not reported for Tulalip Tribes (Toy et al. 1996); values from the Suquamish Tribe (Suquamish Tribe 2000) were used as surrogates.

^c No Tulalip Tribe respondents reported the consumption of benthic whole-body fish (Toy et al. 1996).

^d Values from the Suquamish Tribe (Suquamish Tribe 2000).

CT – central tendency

EPA – US Environmental Protection Agency

na – not applicable

RME – reasonable maximum exposure

3.3.1.2 Child tribal seafood consumption based on Tulalip data

EPA noted in their initial framework guidance document for selecting and using tribal fish and shellfish consumption rates for risk-based decisions (EPA 2007b) that child-specific rates appropriate for use in the framework are not available from the two Puget Sound studies (Toy et al. 1996; Suquamish Tribe 2000). The two consumption studies included adult-reported child seafood consumption for children under 5 years of age (Tulalip study, n = 21) and under 6 years of age (Suquamish study, n = 31). As discussed previously, the Tulalip Tribes study (Toy et al. 1996) was considered most relevant for the EW. Thus, the child tribal exposure scenarios were developed based on data from the Tulalip Tribes consumption study. EPA specified for the LDW HHRA that the total consumption rate for the child tribal RME scenario based on Tulalip data should be equal to 40% of the adult tribal RME consumption rate based on Tulalip data (EPA 2006). The rationale provided by EPA (2007a) included concerns about the small number of children surveyed in the Tulalip Tribes study (i.e., low sample size) and the relatively low consumption rates reported as compared to other regional tribal fish and seafood consumption studies (CRITFC 1994; Toy et al. 1996) and national fish consumption studies (EPA 2002b). The 40% ratio is based on a comparison of child and adult fish and seafood consumption data from regional and national studies (EPA 2006, 2007a). A child tribal CT scenario based on Tulalip data was also developed with a total seafood consumption rate equal to 40% of the adult tribal CT total seafood consumption rate based on Tulalip data (Hiltner 2007).

The limitations in sample size for estimating childhood consumption rates also limit these data for use in estimating the seafood categories consumed by children. Therefore, as was done for the LDW HHRA, the same percentages for consumption of the different seafood categories and portions used for the adult tribal scenario based on Tulalip data (Tables 3-12 through 3-15) were used for the EW child tribal scenarios (i.e., adult tribal RME and CT consumption rates based on Tulalip data for each seafood category and portion were multiplied by 40% to estimate child tribal RME and CT consumption rates based on Tulalip data) (Table 3-16). Thus, no child-specific data from the Tulalip study, other than body weight, was used for the development of the child tribal exposure scenarios based on Tulalip data (Tables 3-6 and 3-7) (Toy et al. 1996). As with the adult tribal seafood consumption scenarios based on Tulalip data, consumption of anadromous fish was not included for EW child tribal exposures and risk estimates based on Tulalip data (EPA 2005a), which consider only the consumption of resident seafood organisms. The total non-anadromous seafood consumed in the tribal child scenario based on Tulalip data was 38.6 g/day and 6.0 g/day for the RME and CT scenarios, respectively.

Seafood consumption rates based on the 95th percentile of seafood consumption for children reported in the Tulalip Tribes study (Toy et al. 1996) and associated risk estimates for consumption of resident EW seafood will be presented in the uncertainty analysis. As discussed in Section 3.3.1, risk estimates for a child tribal scenario based on Suquamish data will also be presented in the uncertainty analysis.

Table 3-16. Rates of child tribal (RME and CT) seafood consumption based on Tulalip data associated with different seafood categories

Seafood Category	RME Scenario Consumption Rate (g/day)^a	CT Scenario Consumption Rate (g/day)^b
Anadromous fish ^c	38.6	6.0
Pelagic fish – rockfish	0.4	0.08
Pelagic fish – perch	2.8	0.44
Benthic fish, fillet	3.0	0.48
Benthic fish, whole body	0	0
Crab, edible meat	10.4	1.6
Crab, whole body	3.3	0.5
Clams	15.7	2.4
Mussels	0.32	0.04
Geoduck, edible meat	2.6	0.4
Geoduck, whole body	0.4	0.04

^a Total consumption rate = 77.6 g/day. Total consumption rate and consumption rates for seafood categories calculated as 40% of the adult tribal RME consumption rates based on Tulalip data (Tables 3-12 through 3-15).

^b Total consumption rate = 12 g/day. Total consumption rate and consumption rates for seafood categories calculated as 40% of the adult tribal CT consumption rates based on Tulalip data (Tables 3-12 through 3-15).

^c Consumption rate will not be used in this HHRA.

CT – central tendency

RME – reasonable maximum exposure

3.3.1.3 Adult API seafood consumption rates

A specific scenario was also developed for adult API consumption of EW seafood. The API populations studied by EPA (1999a) may consume fish and shellfish collected from the EW, but the survey did not include geographic distinctions to determine the fishing frequency in the EW compared to other areas in King County over which the survey was based. However, information collected by Washington State Department of Fish and Wildlife (WDFW) enforcement personnel (Frame 2001) indicate that individuals of API ethnicity are more commonly encountered engaging in non-commercial fishing in the EW than any other ethnic group. Several Puget Sound seafood consumption studies have documented a substantial number of API fishing in urban embayments (Landolt et al. 1985; McCallum 1985; Landolt et al. 1987), including in the EW (King County 1999; EPA 1999a). Although there is uncertainty regarding the degree of seafood consumption by any group within the EW, this HHRA provides an estimate for the API population; this population may consume more seafood than does the general public.

The EPA study included 202 adult men and women from 20 different ethnic groups (Cambodian, Chinese, Filipino, Hmong, Japanese, Korean, Laotian, Mien, Samoan, and

Vietnamese) (EPA 1999a). As in the adult tribal consumption rates based on Tulalip data, EPA provided guidance on the application of data from this study for deriving fish and shellfish consumption rates for risk assessment (Kissinger 2005). An approach similar to that used for the development of tribal rates was used for API consumption rate development. The raw data were used to estimate the 95th percentile of consumption by individuals reporting consumption of seafood caught in King County.

Unlike the tribal studies, however, where each individual respondent was weighted equally, the respondents in the API study were weighted to reflect their ethnic group's population in King County relative to their representation in the consumption study. For example, 20 of the study participants were Cambodian, representing 10% of the survey respondents (20/202). However, Cambodians make up only 3.91% of the total King County population of the 10 ethnic groups included in the study (EPA 1999a). Thus, Cambodians were over-represented in the survey relative to the populations of the other nine API groups in King County. To account for this over-representation, consumption data from each Cambodian respondent was weighted specifically to adjust for this difference (Kissinger 2005). The same was done for each respondent based on their ethnicity and the representation of their ethnicity in the study relative to the representation of their ethnicity in the King County API population.

In EPA's 2005 reanalysis of the 1999 API data, only data for individuals consuming seafood from King County were included; weights based on all participants in the survey were not developed. Weighting factors for King County consumers for various ethnic groups were a function of the percentage of that ethnic group as determined in the census and the number of individuals in that ethnic group that consumed seafood from King County. For example, the weighting factor for Cambodians was derived based on the fact that 11 out of 20 Cambodians consumed seafood harvested in King County, that the percentage of Cambodians in the 2000 US census for King County was 3.91%, and that there were 99 King County seafood consumers in the 1999 API study. The 95th percentile ingestion rate was developed from the consumer-only dataset of weighted ingestion rates.

The data were also adjusted to account for the fact that some shellfish consumption was reported on a cooked-weight basis, rather than on a raw-weight basis. Consumption of the following shellfish was recorded in terms of cooked weight: butter clams, cockles, crabs, geoducks, horse clams, *Macoma* clams, Manila/little neck clams, moon snails, and mussels (EPA 1999a). Consumption of soft-shell clams (*Mya arenaria*) was not recorded; it should be noted that soft-shell clams are the dominant clam present in the LDW. Two revised estimates of average (consumer and non-consumer) raw shellfish consumption were made by EPA, using 25% and 50% cooking loss correction factors for those shellfish species for which consumption was reported on a cooked-weight basis. The average of these two estimates was provided by EPA (Kissinger 2006a).⁶ This approach

⁶ This calculation required access to the information beyond what was provided in the publicly available report (EPA 1999a).

for adjusting cooked weight is described in detail in the EPA guidance document for developing API consumption rates (Kissinger 2005). The recommended 95th percentile of total King County API seafood consumption in that document was 57.1 g/day (n=99, demographically weighted).

To apportion the total seafood consumption rate of 57.1 g/day into the different seafood categories, EPA calculated demographically weighted mean ingestion rates for each seafood category for individuals who consumed some seafood caught in King County. The demographically weighted mean ingestion rates were then used to derive the percentage of consumption of each seafood category (Table 3-17). These percentages were then applied to the total consumption rate (57.1 g/day) to derive consumption rates for each seafood category (Table 3-17). Anadromous fish were not included in the exposure scenario because of the lack of linkage between chemicals in LDW sediments and those found in adult salmon tissues, consistent with the LDW HHRA and per EPA recommendation (EPA 2005a). To estimate the CT consumption rate for the API scenario, the 50th percentile of total King County API consumption (5.8 g/day) (Kissinger 2005) was multiplied by the percentage of consumption for the various seafood categories. Total non-anadromous seafood consumption for the API scenarios was 51.6 g/day and 5.3 g/day for the RME and CT scenarios, respectively.

Table 3-17. Percentages and rates of adult API RME and CT seafood consumption associated with different seafood categories

Seafood Category	Percentage of Consumption ^a	RME Scenario Consumption Rate (g/day) ^b	CT Scenario Consumption Rate (g/day) ^b
Anadromous fish ^c	9.6	5.5	0.56
Pelagic fish	8.6	4.9 ^d	0.5
Benthic fish	4.2	2.4 ^d	0.24
Shellfish	77.5	44.3 ^d	4.6

^a Calculated from average consumption rates by seafood category for consumers of King County species as provided by EPA (Kissinger 2006a).

^b For the RME scenario, the 95th percentile of total King County API seafood consumption, 57.1 g/day (Kissinger 2005), was multiplied by the percentage of consumption for the various seafood categories. For the CT scenario, the 50th percentile of total King County API consumption, 5.8 g/day (Kissinger 2005), was multiplied by the percentage of consumption for the various seafood categories.

^c Consumption rate will not be used in this HHRA.

^d Freshwater fish make up 8.3% of API seafood consumption. As requested by EPA, freshwater fish were apportioned into benthic fish, pelagic fish, and shellfish categories according to the respective consumption rates for those types of fish (EPA 2006). This apportionment assumes that API consumers who catch and consume freshwater fish outside the EW would instead catch and consume more marine species inside the EW.

API – Asian and Pacific Islander

CT – central tendency

EPA – US Environmental Protection Agency

HHRA – human health risk assessment

RME – reasonable maximum exposure

To calculate the consumption of mussels, crabs, and clams for the API scenario, the same general approach as that for the tribal consumption calculations was used. The

average demographically weighted consumption of clams, mussels, and crabs for the API consumers of these shellfish species self-harvested only from King County (n = 99) was provided by EPA (Kissinger 2006a) and used to calculate the percentage of each shellfish type consumed (Table 3-18) (Kissinger 2006a). This weighting factor was used with the estimate of the 95th percentile of King County API shellfish consumption (44.3 g/day, Table 3-17) to calculate the consumption of clams, mussels, and crabs. Consumption of pelagic fish was apportioned based on reported consumption within these categories (Table 3-19). As with the tribal consumption estimate, the crab consumption rates were apportioned among crab whole body and edible meat, and the benthic fish consumption rates were apportioned among benthic fish fillet and whole body (Table 3-20) based on the reported consumption of these seafood tissue categories by API consumers.⁷ This information was provided by EPA as demographically weighted average percentages of crab whole-body and crab edible-meat consumption by API members consuming at least some King County seafood (n = 96; 3 individuals did not consume any crab) (Kissinger 2007a). Similarly, EPA provided the average demographically weighted percentages of whole-body versus fillet consumption by API members consuming at least some King County seafood (n = 99) (Kissinger 2007a). This latter information was used to apportion benthic fish consumption into benthic whole-body and benthic fillet consumption.

Table 3-18. Adult API RME and CT consumption of shellfish (crabs, clams, and mussels)

Shellfish Type	Percentage of Total Shellfish Consumption ^a	RME Scenario Consumption Rate (g/day) ^{b, c}	CT Scenario Consumption Rate (g/day) ^{b, c}
Crabs	24.0	10.6	1.1
Clams ^d	65.6	29.1	3.0
Mussels	10.4	4.6	0.47

^a Calculated from average consumption rates provided by EPA for API consumers of King County species (Kissinger 2006b).

^b Product of percentage of total shellfish consumption (for each shellfish type) and total shellfish consumption (Table 3-17).

^c Consumption includes freshwater fish.

^d Includes Manila/littleneck clams, horse clams, butter clams, cockles, oysters, and scallops.

API – Asian and Pacific Islander

CT – central tendency

EPA – US Environmental Protection Agency

RME – reasonable maximum exposure

⁷ Because of the low sample size, both self-harvesters and non-self-harvesters were used to estimate portions of crab and benthic fish consumed.

Table 3-19. Adult API RME and CT consumption of pelagic fish (perch and rockfish)

Shellfish Type	Percentage of Total Pelagic Fish Consumption ^a	RME Scenario Consumption Rate (g/day) ^{b, c}	CT Scenario Consumption Rate (g/day) ^{b, c}
Perch	10	0.5	0.05
Rockfish	90	4.4	0.45

^a Calculated from average consumption rates provided by EPA for API consumers of King County species (provided by Lon Kissinger (Kissinger 2008)). Reported consumption of herring was used as a surrogate for consumption of perch, which was not reported.

^b Product of percentage of total consumption and total pelagic fish consumption.

^c Consumption includes freshwater fish.

API – Asian and Pacific Islander

CT – central tendency

EPA – US Environmental Protection Agency

RME – reasonable maximum exposure

Table 3-20. Portions of benthic fish and crab consumed – adult API RME and CT scenarios

Seafood Category	Percentage of Consumption ^a	RME Scenario Consumption Rate (g/day) ^{b, c}	CT Scenario Consumption Rate (g/day) ^{b, c}
Crab, edible meat	53.3	5.7	0.6
Crab, whole body	46.7	4.9	0.5
Benthic fish, fillet	82.3	2.0	0.2
Benthic fish, whole body	17.7	0.4	0.04

^a As provided by EPA for crab or fish (Kissinger 2007a) for API consumers of King County species.

^b Percentage of consumption multiplied by total crab consumption (Table 3-18) or total benthic fish consumption (Table 3-17).

^c Consumption includes freshwater fish.

API – Asian and Pacific Islander

CT – central tendency

EPA – US Environmental Protection Agency

RME – reasonable maximum exposure

Unlike the consumption scenarios based on Tribal data, the API seafood scenario does not include geoduck consumption as a portion of total shellfish consumption. The tribes that have Usual and Accustomed (U&A) rights in the EW commercially harvest geoducks and therefore have the equipment (i.e., scuba gear) needed to collect them. However, the API population does not have commercial harvesting rights to geoducks in the EW. Because of this and the fact that special equipment and training in its use are required to harvest geoducks, the API population was assumed not to consume geoducks from the EW.

3.3.1.4 Adult one-meal-per-month seafood consumption rates

Consumption rates for recreationally caught fish are not available for the EW. Although there have been some creel studies conducted in the LDW/EW area (Landolt et al. 1985; McCallum 1985), there has not been a comprehensive recreational fish consumption study for the EW site or nearby areas of similar quality as the recent tribal studies (Toy et al. 1996; Suquamish Tribe 2000) and API studies (EPA 1999a). Recreational fishing is known to occur on the EW despite the existence of fishing advisories (King County 1999), but the magnitude is uncertain. It is expected that current recreational consumption of resident species is likely to be relatively low and potentially suppressed because of public awareness of chemical contamination in the EW and LDW and WSDOH seafood consumption advisories for the EW and LDW (WSDOH 2005). However, in addition to commercial salmon fishing, many individuals also engage in salmon angling in the EW (King County 1999).

In an effort to provide information that would allow site users to evaluate the risks associated with seafood consumption, four hypothetical scenarios were developed. To evaluate risks associated with consumption of various resources independently (i.e., in addition to the market basket approach applied for the tribal seafood consumption evaluation), the consumption of different seafood categories will be evaluated independently for benthic fish (fillets), pelagic fish, clams, and crabs (edible meat). Each scenario assumes that consumption would average approximately one meal (227 g, per EPA (2000) guidance) per month of a given seafood category, which equates to 7.5 g/day. Totaling the risks from each of these four scenarios provides an estimate of risk associated with four meals per month, one of each seafood category, although data to support this quantity and pattern of recreational consumption for current or future use are lacking. The one-meal-per-month seafood consumption scenario and the associated risk estimates are intended to serve as a tool for risk communication and are not intended to directly reflect actual recreational seafood consumption because these rates are highly uncertain and may currently be suppressed as a result of consumption advisories.

One-meal-per-month scenarios will include specific targeted species and seafood portions expected to reflect what individuals might choose to consume. The benthic fish one-meal per month scenario will evaluate the consumption of English sole fillets. The pelagic one-meal-per-month scenario will be evaluated for perch and rockfish separately (i.e., as two independent scenarios). The crab one-meal-per-month scenario will evaluate only the consumption of crab edible meat. Finally, the clam one-meal-per-month scenario will include clams collected from intertidal areas⁸. The one-meal-per-month scenarios provide a basis for individuals to evaluate their own exposure using a method that is readily scaled to various seafood consumption levels. For example, if someone eats two meals per month of EW crab and one meal per month of EW pelagic

⁸ Geoducks are not included in non-tribal scenarios because geoducks are harvested with scuba gear and other specialized tools.

fish, he or she could multiply the one-meal-per-month crab risk estimate by two and add the product to the one-meal-per-month pelagic fish risk estimate to approximate the risk associated with his or her own EW seafood consumption. A graphical representation of seafood consumption rates versus risk estimates will be presented by species to make scaling (e.g., one crab meal per month to one crab meal per week) easier for the public.

As with the tribal and API scenarios and based on EPA recommendations, consumption of adult salmon from the EW will be excluded from the HHRA (EPA 2005a). Thus, although salmon have been identified as the most commonly sought species for recreational fishers in the EW (King County 1999), bioaccumulative chemical concentrations in adult salmon in the EW are believed to be largely attributable to uptake during their migrations far beyond the EW, and thus most of the risks associated with consumption of adult salmon are not related to EW sediments. Therefore, the adult one-meal-per-month exposure scenarios derived here do not address risks from the consumption of adult salmon from the EW.

3.3.2 Sediment exposure scenarios and parameters

As indicated in the CSM, direct exposure to sediment may occur through occupational or recreational activities. Several scenarios will be evaluated for the EW in an effort to capture the range of potential exposure magnitude (i.e., the amount of skin exposure to sediment and the amount of sediment incidentally ingested), frequency of exposure, and exposure areas within the EW. Workers involved in commercial netfishing in the EW may come in contact with sediment. The gillnet lead lines typically come in contact with sediments during normal operations. The netfishers may contact this sediment incidentally upon net retrieval and may then also have incidental contact with sediment suspended in surface water. People conducting intertidal habitat restoration routinely come in contact with sediment, though the frequency and duration of exposure would be expected to be less than that for tribal netfishing. Finally, tribal members and the general public may choose to collect clams in intertidal areas of the EW.⁹ The exposure parameters for these scenarios are the same as those used for the LDW HHRA (Windward 2007c).

3.3.2.1 Summary of human access survey results

As discussed in the human access survey report (Windward 2008a), there are currently only three areas in the EW where the general public can access the shoreline from upland areas: Jack Perry Memorial Park, Terminal 102, and the shoreline below the

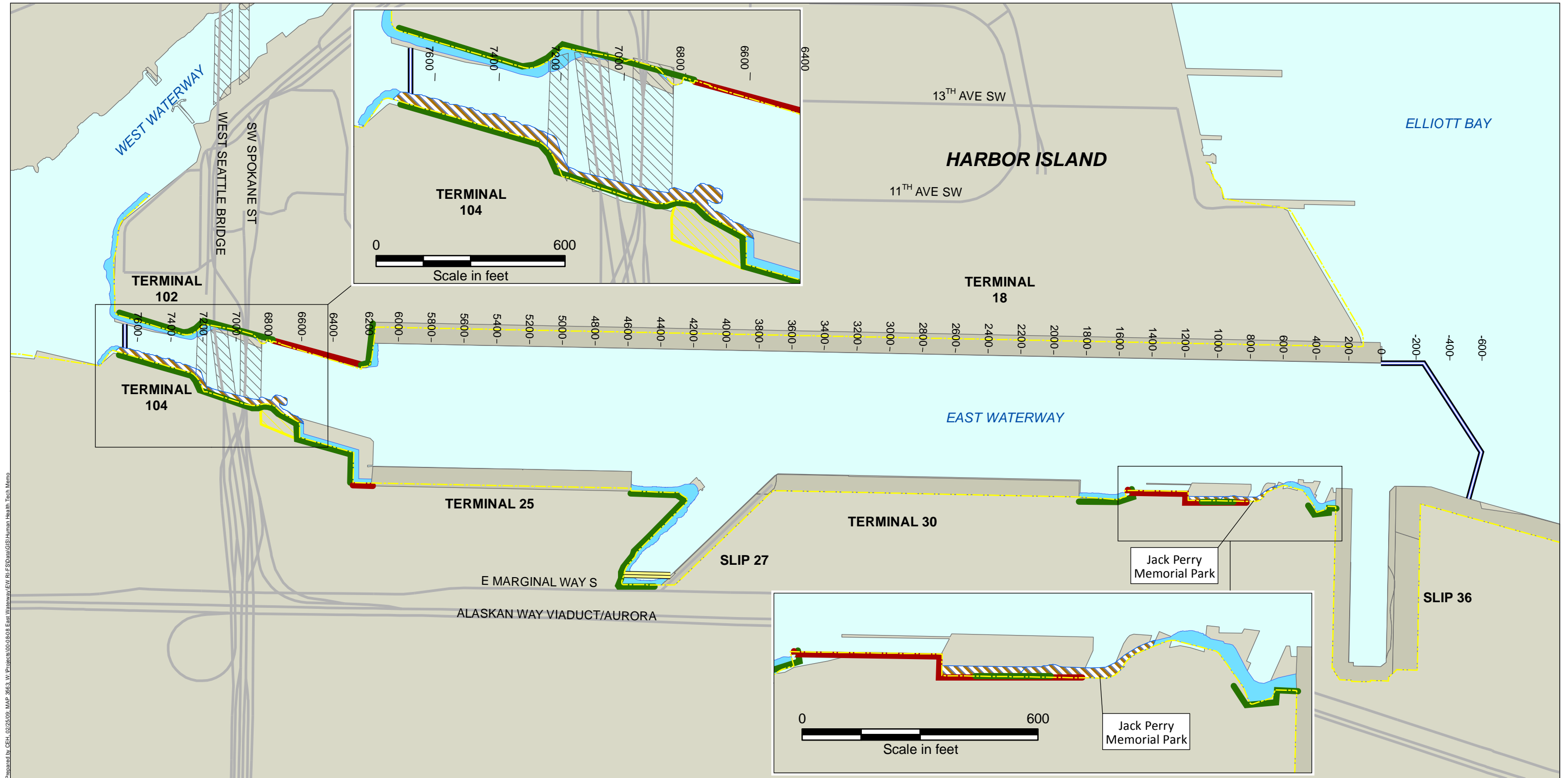
⁹ Tribal members may also collect geoducks subtidally. However, risks associated with dermal sediment exposure are unlikely because individuals engaged in geoduck collection must wear scuba gear, (e.g., wet- or dry-suits, face masks, and gloves), which would insulate them from the cold water as well as protect them from sediment exposure. Thus, an exposure scenario specific to geoduck collection (i.e., a subtidal sediment exposure specific to clamming) will not be evaluated in the EW HHRA. However, exposure to subtidal sediment will be addressed in the fish collection (netfishing) scenario, which includes exposure to all surface sediment in the EW, both intertidal and subtidal.

bridge complex (West Seattle Bridge, Spokane Street Bridge, and railroad bridge). There are a few intertidal areas that may change from restricted to public access areas in the future (e.g., the bank north of the Spokane Street Bridge on the east side of the EW). Restrictions on intertidal shoreline areas presented in the survey results apply to the general public. Members of the Suquamish and Muckleshoot Tribes have Usual and Accustomed fishing rights throughout the EW and do not have access restrictions, including areas where intertidal sediments are present. They have access to all available intertidal areas of the EW shoreline.

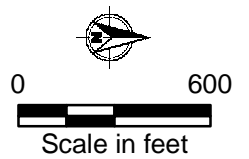
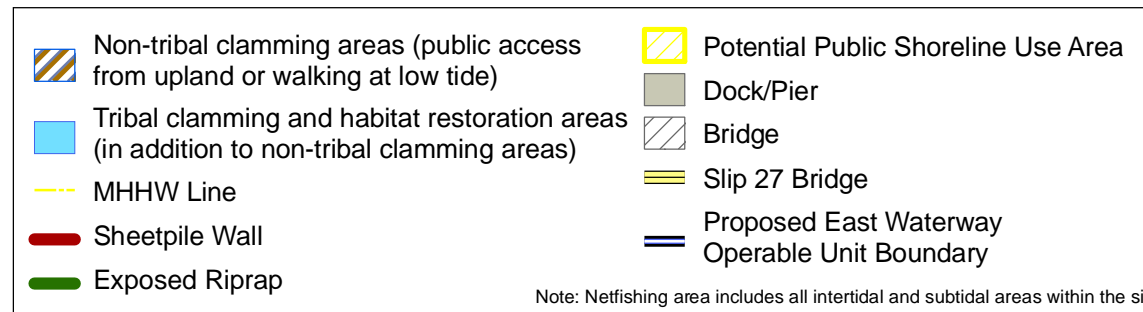
3.3.2.2 Exposure areas and parameters

Two commercial netfishing scenarios will be evaluated for adult exposures: a CT scenario that assumes a typical frequency and duration of netfishing activity, as recommended by EPA, and an RME scenario that assumes more frequent and longer-term netfishing. For tribal clamming, an RME (120 days -per year) and a 183-day-per-year scenario will be evaluated. There will be one habitat restoration scenario evaluated. The exposure areas for netfishing will be assumed to cover the entire study area of the EW. Data from sediment samples taken from throughout the waterway, including intertidal and subtidal areas, will be included. For the tribal clamming and habitat restoration scenarios, the exposure areas will include sediment samples from all intertidal areas not covered by overhanging docks. Exposure units for the intertidal exposure scenarios (i.e. habitat restoration and clamming) are indicated on Map 3-1. The netfishing, habitat restoration worker, and clamming scenarios for EW will utilize the same exposure parameters as those used for the LDW HHRA (Windward 2007c).

For non-tribal clamming, a 7-day-per-year scenario will be evaluated. This exposure frequency was assumed to be once per month during months when there is a daylight minus tide, based on NOAA tidal information (NOAA 2006) from 2004 through 2006. As previously discussed (Section 3.3.2.1.) based on findings from the human access survey (Windward 2008a), there are currently only a few areas in the EW where the general public can access the shoreline from upland: Jack Perry Memorial Park, Terminal 102, and the shoreline below the West Seattle Bridge, Spokane Street Bridge, and railroad bridge. However, at Terminal 102, there is no intertidal sediment so clamming is not possible. Therefore, the exposed sediment at the other areas will make up the exposure area for the 7-day-per-year non-tribal clamming scenario (Map 3-1).



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Map 3-1
Direct contact sediment exposure areas,
proposed East Waterway operable unit

This section provides a summary of the CDI calculations for COPCs for sediment exposure as well as details on the exposure parameters used to evaluate each sediment exposure scenario. Exposure to COPCs in sediment is expressed as the CDI, which is the estimated daily chemical dose for an individual that occurs over the exposure duration for each scenario. Two routes of exposure are relevant: ingestion and dermal contact. The CDI for ingestion (which is calculated the same way as for the ingestion of seafood) is calculated as:

$$CDI_o = \frac{EPC \times IR \times FI \times EF \times ED \times CF}{BW \times AT} \quad \text{Equation 3-2}$$

Where:

- CDI_o = chronic daily intake from oral exposure route (mg/kg-day)
- EPC = chemical-specific exposure point concentration (mg/kg)
- IR = sediment ingestion rate (g/day)
- FI = fractional intake of media derived from contaminated source (unitless)
- EF = exposure frequency (days per year)
- ED = exposure duration (years)
- CF = conversion factor (kg/g)
- BW = body weight (kg)
- AT = averaging time (days), equivalent to the ED for non-carcinogenic COPCs and 70 years for carcinogenic COPCs

The CDI for dermal exposure¹⁰ is calculated as:

$$CDI_d = \frac{EPC \times ABS \times SA \times AF \times FI \times EF \times ED \times CF}{BW \times AT} \quad \text{Equation 3-3}$$

Where:

- CDI_d = chronic daily intake from dermal exposure route (mg/kg-day)
- EPC = chemical-specific exposure point concentration (mg/kg)
- ABS = dermal absorption factor (unitless)
- SA = skin surface area exposed (cm²)
- AF = sediment to skin adherence factor by event (mg/cm²-event)
- FI = fractional intake of media derived from contaminated source (unitless)
- EF = exposure frequency (events/year)
- ED = exposure duration (years)
- CF = conversion factor (kg/mg)
- BW = body weight (kg)
- AT = averaging time (days)

¹⁰ Although chronic daily intake technically refers to oral exposure only, this term will also be used in the HHRA to refer to dermal exposure, which is technically an absorbed dose. For this HHRA, the adjustment between orally administered doses and dermally administered doses will be made by adjusting the oral toxicological benchmarks, as appropriate, according to EPA guidance (2004b).

Two parameters that warrant additional discussion, dermal adherence factor (AF) and dermal absorption factor, are discussed in Sections 3.3.2.1 and 3.3.2.2.

Sediment exposure scenarios are described in Table 3-21 for netfishing, habitat restoration, and clamming. All scenarios include exposures from dermal contact and incidental ingestion of sediment. Most of the exposure parameters relative to these exposure routes are provided in Tables 3-22 to 3-33.

Table 3-21. Summary of sediment exposure scenarios

Scenario	Incidental Sediment IR (g/day)	Exposure Frequency (days/yr)	Exposure Duration (years)	Skin Surface Area Exposed (cm ²)	Location of Scenario-Specific Details	
					Incidental Ingestion	Dermal
Netfishing RME	0.05	119	44	3,600	Table 3-22	Table 3-23
Netfishing CT	0.05	63	29	3,600	Table 3-24	Table 3-25
Habitat restoration worker	0.1	15	20	6,040	Table 3-26	Table 3-27
Clamming 7 days per year	0.1	7	30	6,040	Table 3-28	Table 3-29
Tribal clamming RME	0.1	120	64	6,040	Table 3-30	Table 3-31
Tribal clamming 183 days per year	0.1	183	70	6,040	Table 3-32	Table 3-33

CT – central tendency

IR – ingestion rate

RME – reasonable maximum exposure

Table 3-22. Daily intake calculations – incidental sediment ingestion during netfishing, adult tribal RME scenario

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Sediment Exposure route: Ingestion (incidental) Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = $EPC \times IR-s \times FI \times EF \times ED \times CF \times 1/BW-a \times 1/AT$				
Parameter Code	Parameter Definition	Units	Value	Rationale/Reference
EPC	exposure point concentration in sediment	mg/kg dw	TBD	Section 3.3.4
IR-s	incidental ingestion rate	g/day	0.050	EPA (1991)
FI	fractional intake derived from source	unitless	1 ^a	na
EF	exposure frequency	days/yr	119 ^b	na
ED	exposure duration	years	44 ^b	na
CF	conversion factor	kg/g	0.001	na
BW-a	body weight – adult	kg	81.8	Toy et al. (1996)
AT-C	averaging time – cancer	days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	days	16,060	EPA (1989)

Source: Standard Table 4 in EPA (1998)

^a Fractional intake of 1 will be used to be consistent with EPA direction for seafood consumption scenarios.

^b Value recommended by EPA based on the length of the 2001 salmon season and on conversations with Muckleshoot Indian Tribe Assistant Harvest Manager regarding fishing frequency. This approach assumes that a fisher is present for each day of the fishing season. See Subappendix B.3 in Windward (2003) for more details on the derivation of this value.

dw – dry weight

EPA – US Environmental Protection Agency

na – not applicable

RME – reasonable maximum exposure

TBD – to be determined

Table 3-23. Daily intake calculations – dermal contact with sediment during netfishing, adult tribal RME scenario

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Sediment Exposure route: Dermal Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = $EPC \times ABS \times SA \times AF \times FI \times EF \times ED \times CF \times 1/BW-a \times 1/AT$				
Parameter Code	Parameter Definition	Units	Value	Rationale/Reference
EPC	exposure point concentration in sediment	mg/kg dw	TBD	Section 3.3.4
ABS	dermal absorption factor	unitless	Table 3-34	Section 3.3.2
SA	skin surface area exposed	cm ²	3,600 ^a	EPA (1997)
AF	adherence factor by event	mg/cm ² -event	0.2	EPA (1999b)
FI	fractional intake derived from source	unitless	1 ^b	na
EF	exposure frequency	events/yr	119 ^c	na
ED	exposure duration	years	44 ^c	na
CF	conversion factor	kg/mg	0.000001	na
BW-a	body weight – adult	Kg	81.8	Toy et al. (1996)
AT-C	averaging time – cancer	days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	days	16,060	EPA (1989)

Source: Standard Table 4 in EPA (1998)

- ^a Recommended surface area for commercial/industrial worker. Assumes that head, hands, and forearms are exposed. Selected value represents sum of 50th percentile surface areas for men (most netfishers are men) for these body parts; taken from Table 6-2 in EPA (1997). Given the higher body weight of individuals surveyed in Toy et al. (1996) compared to the general US population, the surface area values selected here for commercial/industrial workers may underestimate the surface area of tribal fishermen body parts. However, no conversion data are available at the present time.
- ^b Fractional intake of 1 will be used to be consistent with EPA direction for seafood consumption scenarios.
- ^c Value recommended by EPA based on conversation with Muckleshoot Indian Tribe Assistant Harvest Manager. See Subappendix B.3 in Windward (2003) for more details on the derivation of this value.

dw – dry weight

EPA – US Environmental Protection Agency

na – not applicable

RME – reasonable maximum exposure

TBD – to be determined

Table 3-24. Daily intake calculations – incidental sediment ingestion during netfishing, adult tribal CT scenario

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Sediment Exposure route: Ingestion (incidental) Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = $EPC \times IR-s \times FI \times EF \times ED \times CF \times 1/BW-a \times 1/AT$				
Parameter Code	Parameter Definition	Units	Value	Rationale/Reference
EPC	exposure point concentration in sediment	mg/kg dw	TBD	Section 3.3.4
IR-s	incidental ingestion rate	g/day	0.050	EPA (1991)
FI	fractional intake derived from source	unitless	1 ^b	na
EF	exposure frequency	days/yr	63 ^c	na
ED	exposure duration	years	29 ^d	na
CF	conversion factor	kg/g	0.001	na
BW-a	body weight – adult	kg	81.8	Toy et al. (1996)
AT-C	averaging time – cancer	days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	days	10,585	EPA (1989)

Source: Standard Table 4 in EPA (1998)

^a EPCs for CT scenarios are based on mean concentrations, in contrast to the EPCs for the RME scenarios, which are based on 95% UCLs on mean concentrations.

^b Fractional intake of 1 will be used to be consistent with EPA direction for seafood consumption scenarios.

^c Value recommended by EPA based on conversation with Muckleshoot Indian Tribe Assistant Harvest Manager. Selected value is duration of coho fishing season (most individuals fish for coho). See Appendix B, Section B.3, in Windward (2003) for more details on the derivation of this value.

^d Value recommended by EPA based on conversation with Muckleshoot Indian Tribe Assistant Harvest Manager. Selected value is EPA's best professional judgment assuming that fishing starts at age 16 and ends at age 45.

CT – central tendency

dw – dry weight

EPA – US Environmental Protection Agency

na – not applicable

TBD – to be determined

UCL – upper confidence limit on the mean

Table 3-25. Daily intake calculations – dermal contact with sediment during netfishing, adult tribal CT scenario

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Sediment Exposure route: Dermal Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = $EPC \times ABS \times SA \times AF \times FI \times EF \times ED \times CF \times 1/BW-a \times 1/AT$				
Parameter Code	Parameter Definition	Units	Value	Rationale/ Reference
EPC	exposure point concentration in sediment	mg/kg dw	TBD	Section 3.3.4
ABS	dermal absorption factor	unitless	Table 3-34	Section 3.3.2
SA	skin surface area exposed	cm ²	3,600 ^b	EPA (1997)
AF	adherence factor by event	mg/cm ² -event	0.02 ^c	EPA (2004b)
FI	fractional intake derived from source	unitless	1 ^d	na
EF	exposure frequency	event/ year	63 ^e	na
ED	exposure duration	years	29 ^f	na
CF	conversion factor	kg/mg	0.000001	na
BW-a	body weight – adult	Kg	81.8	Toy et al. (1996)
AT-C	averaging time – cancer	days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	days	10,585	EPA (1989)

Source: Standard Table 4 in EPA (1998)

^a EPCs for CT scenarios are based on mean concentrations, in contrast to the EPCs for the RME scenarios, which are based on 95% UCLs on mean concentrations.

^b Recommended surface area for commercial/industrial worker. Assumes that head, hands, and forearms are exposed. Selected value represents sum of 50th percentile surface areas for men (most netfishers are men) for these body parts; taken from Table 6-2 in EPA (1997). Given the higher body weight of individuals surveyed in Toy et al. (1996) compared to the general US population, the surface area values selected here for commercial/industrial workers may underestimate the surface area of tribal fishermen body parts. However, no conversion data are available at the present time.

^c Default value for CT industrial workers in Risk assessment guidance for Superfund (RAGS) Part E (EPA 2004b).

^d Fractional intake of 1 will be used to be consistent with EPA direction for seafood consumption scenarios.

^e Value recommended by EPA based on conversation with Muckleshoot Indian Tribe Assistant Harvest Manager. Selected value is duration of coho fishing season (most individuals fish for coho). See Subappendix B.3 in Windward (2003) for more details on the derivation of this value.

^f Value recommended by EPA based on conversation with Muckleshoot Indian Tribe Assistant Harvest Manager. Selected value is EPA's best professional judgment assuming that fishing starts at age 16 and ends at age 45.

CT – central tendency

dw – dry weight

EPA – US Environmental Protection Agency

na – not applicable

TBD – to be determined

UCL – upper confidence limit on the mean

Table 3-26. Daily intake calculations –incidental sediment ingestion during habitat restoration

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Sediment Exposure route: Ingestion (incidental) Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = $EPC \times IR-s \times FI \times EF \times ED \times CF \times 1/BW-a \times 1/AT$				
Parameter Code	Parameter Definition	Units	Value	Rationale/ Reference
EPC	exposure point concentration in sediment	mg/kg dw	TBD	Section 3.3.4
IR-s	incidental ingestion rate	g/day	0.1 ^a	EPA (1997)
FI	fractional intake derived from source	unitless	1 ^b	na
EF	exposure frequency	days/yr	15 ^c	na
ED	exposure duration	years	20 ^d	EPA (1989)
CF	conversion factor	kg/g	0.001	na
BW-a	body weight – adult	kg	71.8 ^e	EPA (1997)
AT-C	averaging time – cancer	days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	days	7,300	EPA (1989)

Source: Standard Table 4 in EPA (1998)

^a Default for agricultural and residential exposure (EPA 1997).

^b Fractional intake of 1 will be used to be consistent with EPA direction for seafood consumption scenarios.

^c Assume biologist only on site during a restoration activity. This is consistent with value used in LDW HHRA (Windward 2007c).

^d Accounts for a reasonably long career in the same position, but assumes that the most senior scientists will spend very little time in the field.

^e Mean body weight for male and female adults from Table 7-2 in EPA (1997).

dw – dry weight

EPA – US Environmental Protection Agency

na – not applicable

TBD – to be determined

Table 3-27. Daily intake calculations – dermal contact with sediment during habitat restoration

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Sediment Exposure route: Dermal Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = $EPC \times ABS \times SA \times AF \times FI \times EF \times ED \times CF \times 1/BW-a \times 1/AT$				
Parameter Code	Parameter Definition	Units	Value	Rationale/Reference
EPC	exposure point concentration in sediment	mg/kg dw	TBD	Section 3.3.4
ABS	dermal absorption factor	unitless	Table 3-32	Section 3.3.2
SA _i	skin surface area exposed	cm ²	6,040 ^a	EPA (1997)
AF	adherence factor by event	mg/cm ² -event	0.2 ^b	EPA (2004b)
FI	fractional intake derived from source	unitless	1 ^c	na
EF	exposure frequency	events/yr	15 ^d	na
ED _i	exposure duration	Years	20 ^e	EPA (1989)
CF	conversion factor	kg/mg	0.000001	na
BW-a	body weight – adult	Kg	71.8 ^f	EPA (1997)
AT-C	averaging time – cancer	Days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	Days	7,300	EPA (1989)

Source: Standard Table 4 in EPA (1998)

^a Skin surface area used for adult clamming scenario in this HHRA.

^b Default health-protective factor for exposures of children and adults to moist soil recommended by EPA (2004b).

^c Fractional intake of 1 will be used to be consistent with EPA direction for seafood consumption scenarios.

^d Assume biologist only on site during a restoration activity. This is consistent with value used in LDW HHRA (Windward 2007c).

^e Accounts for a reasonably long career in the same position, but assumes that the most senior scientists will spend very little time in the field.

^f Mean body weight for male and female adults from Table 7-2 in EPA (1997).

dw – dry weight

EPA – US Environmental Protection Agency

na – not applicable

TBD – to be determined

Table 3-28. Daily intake calculations –incidental sediment ingestion during clamming, 7-day-per-year scenario

Scenario timeframe: Current/future
Medium: Sediment
Exposure medium: Sediment
Exposure route: Ingestion (incidental)
Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = $EPC \times IR-s \times FI \times EF \times ED \times CF \times 1/BW-a \times 1/AT$

Parameter Code	Parameter Definition	Units	Value	Rationale/Reference
EPC	exposure point concentration in sediment	mg/kg dw	TDB	Section 3.3.4
IR-s	incidental ingestion rate	g/day	0.1	EPA (1997)
FI	fractional intake derived from source	unitless	1 ^a	na
EF	exposure frequency	days/yr	7 ^b	na
ED	exposure duration	years	30	EPA (1989)
CF	conversion factor	kg/g	0.001	na
BW-a	body weight – adult	kg	71.8 ^c	EPA (1997)
AT-C	averaging time – cancer	days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	days	10,950	EPA (1989)

Source: Standard Table 4 in EPA (1998)

^a Fractional intake of 1 will be used to be consistent with EPA direction for seafood consumption scenarios.

^b Exposure frequency was assumed to be once per month during months when there is a daylight minus tide, based on NOAA tidal information (NOAA 2006) from 2004 through 2006.

^c Mean body weight for male and female adults from Table 7-2 in EPA (1997).

dw – dry weight

EPA – US Environmental Protection Agency

na – not applicable

TBD – to be determined

Table 3-31. Daily intake calculations – dermal contact with sediment during clamming, 7-day-per-year scenario

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Sediment Exposure route: Dermal Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = $EPC \times ABS \times SA \times AF \times FI \times EF \times ED \times CF \times 1/BW-a \times 1/AT$				
Parameter Code	Parameter Definition	Units	Value	Rationale/Reference
EPC	exposure point concentration in sediment	mg/kg dw	TBD	Section 3.3.4
ABS	dermal absorption factor	unitless	Table 3-32	Section 3.3.2
SA _i	skin surface area exposed	cm ²	6,040 ^a	EPA (1997)
AF	adherence factor by event	mg/cm ² -event	0.2	EPA (2004b)
FI	fractional intake derived from source	unitless	1 ^b	na
EF	exposure frequency	events/yr	7 ^c	na
ED _i	exposure duration	Years	30	EPA (1989)
CF	conversion factor	kg/mg	0.000001	na
BW-a	body weight – adult	Kg	71.8 ^d	EPA (1997)
AT-C	averaging time – cancer	Days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	Days	10,950	EPA (1989)

Source: Standard Table 4 in EPA (1998)

- ^a Assumes that 39% of the total body surface area is exposed, roughly corresponding to a barefoot individual wearing a short-sleeve shirt and short pants (EPA 1992). Body surface area data taken from Tables 6-2, 6-3 and 6-4 in EPA (1997) and corresponds to head, lower arms, hands, lower legs, and feet.
- ^b Fractional intake of 1 will be used to be consistent with EPA direction for seafood consumption scenarios.
- ^c Exposure frequency was assumed to be once per month during months when there is a daylight minus tide, based on NOAA tidal information (NOAA 2006) from 2004 through 2006.
- ^d Mean body weight for male and female adults from Table 7-2 in EPA (1997).

dw – dry weight

EPA – US Environmental Protection Agency

na – not applicable

TBD – to be determined

Table 3-30. Daily intake calculations – incidental sediment ingestion during tribal clamming RME scenario

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Sediment Exposure route: Ingestion (incidental) Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = $EPC \times IR-s \times FI \times EF \times ED \times CF \times 1/BW-a \times 1/AT$				
Parameter Code	Parameter Definition	Units	Value	Rationale/Reference
EPC	exposure point concentration in sediment	mg/kg dw	TBD	Section 3.3.4
IR-s	Incidental ingestion rate	g/day	0.1	EPA (1997)
FI	fractional intake derived from source	unitless	1 ^a	na
EF	exposure frequency	days/yr	120 ^b	Kissinger (2007b)
ED	exposure duration	Years	64 ^c	Kissinger (2007b)
CF	conversion factor	kg/g	0.001	na
BW-a	body weight – adult	Kg	81.8	Toy et al. (1996)
AT-C	averaging time – cancer	Days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	Days	23,360	EPA (1989)

Source: Standard Table 4 in EPA (1998)

^a Fractional intake of 1 will be used to be consistent with EPA direction for seafood consumption scenarios.

^b Exposure frequency determined by EPA to reflect tribal clamming patterns (Kissinger 2007b).

^c Exposure duration determined by EPA to reflect tribal clamming patterns (Kissinger 2007b).

dw – dry weight

EPA – US Environmental Protection Agency

na – not applicable

TBD – to be determined

Table 3-31. Daily intake calculations – dermal contact with sediment during tribal clamming RME scenario

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Sediment Exposure route: Dermal Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = $EPC \times ABS \times SA \times AF \times FI \times EF \times ED \times CF \times 1/BW-a \times 1/AT$				
Parameter Code	Parameter Definition	Units	Value	Rationale/Reference
EPC	exposure point concentration in sediment	mg/kg dw	TBD	Section 3.3.4
ABS	dermal absorption factor	unitless	Table 3-32	Section 3.3.2
SA _i	skin surface area exposed	cm ²	6,040 ^a	EPA (1997)
AF	adherence factor by event	mg/cm ² -event	0.2	EPA (2004b)
FI	fractional intake derived from source	unitless	1 ^b	na
EF	exposure frequency	events/yr	120	Kissinger (2007b)
ED _i	exposure duration	Years	64	Kissinger (2007b)
CF	conversion factor	kg/mg	0.000001	na
BW-a	body weight – adult	Kg	81.8	Toy et al. (1996)
AT-C	averaging time – cancer	Days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	Days	23,360	EPA (1989)

Source: Standard Table 4 in EPA (1998)

- ^a Assumes that 39% of the total body surface area is exposed, roughly corresponding to a barefoot individual wearing a short-sleeve shirt and short pants (EPA 1992). Body surface area data taken from Tables 6-2, 6-3 and 6-4 in EPA (1997) and corresponds to head, lower arms, hands, lower legs, and feet.
- ^b Fractional intake of 1 will be used to be consistent with EPA direction for seafood consumption scenarios.
- ^c Exposure frequency determined by EPA to reflect tribal clamming patterns (Kissinger 2007b).
- ^d Exposure duration determined by EPA to reflect tribal clamming patterns (Kissinger 2007b).

dw – dry weight

EPA – Environmental Protection Agency

na – not applicable

TBD – to be determined

Table 3-32. Daily intake calculations – incidental sediment ingestion during tribal clamming, 183-day-per-year scenario

Scenario timeframe: Current/future
Medium: Sediment
Exposure medium: Sediment
Exposure route: Ingestion (incidental)
Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = $EPC \times IR-s \times FI \times EF \times ED \times CF \times 1/BW-a \times 1/AT$

Parameter Code	Parameter Definition	Units	Value	Rationale/Reference
EPC	exposure point concentration in sediment	mg/kg dw	TBD	Section 3.3.4
IR-s	Incidental ingestion rate	g/day	0.1	EPA (1997)
FI	fractional intake derived from source	unitless	1 ^a	na
EF	exposure frequency	days/yr	183 ^b	Kissinger (2007b)
ED	exposure duration	Years	70 ^c	Kissinger (2007b)
CF	conversion factor	kg/g	0.001	na
BW-a	body weight – adult	Kg	81.8	Toy et al. (1996)
AT-C	averaging time – cancer	Days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	Days	25,550	EPA (1989)

Source: Standard Table 4 in EPA (1998)

^a Fractional intake of 1 will be used to be consistent with EPA direction for seafood consumption scenarios.

^b Exposure frequency requested by Muckleshoot and Suquamish Tribes (Kissinger 2007b).

^c Exposure duration requested by Muckleshoot and Suquamish Tribes (Kissinger 2007b).

dw – dry weight

EPA – US Environmental Protection Agency

na – not applicable

TBD – to be determined

Table 3-33. Daily intake calculations – dermal contact with sediment during tribal clamming, 183-day-per-year scenario

Scenario timeframe: Current/future Medium: Sediment Exposure medium: Sediment Exposure route: Dermal Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = $EPC \times ABS \times SA \times AF \times FI \times EF \times ED \times CF \times 1/BW-a \times 1/AT$				
Parameter Code	Parameter Definition	Units	Value	Rationale/Reference
EPC	exposure point concentration in sediment	mg/kg dw	TBD	Section 3.3.4
ABS	dermal absorption factor	unitless	Table 3-32	Section 3.3.2
SA _i	skin surface area exposed	cm ²	6,040 ^a	EPA (1997)
AF	adherence factor by event	mg/cm ² -event	0.2	EPA (2004b)
FI	fractional intake derived from source	unitless	1 ^b	na
EF	exposure frequency	events/yr	183 ^c	Kissinger (2007b)
ED _i	exposure duration	Years	70 ^d	Kissinger (2007b)
CF	conversion factor	kg/mg	0.000001	na
BW-a	body weight – adult	Kg	81.8	Toy et al. (1996)
AT-C	averaging time – cancer	Days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	Days	25,550	EPA (1989)

Source: Standard Table 4 in EPA (1998)

- ^a Assumes that 39% of the total body surface area is exposed, roughly corresponding to a barefoot individual wearing a short-sleeve shirt and short pants (EPA 1992). Body surface area data taken from Tables 6-2, 6-3 and 6-4 in EPA (1997) and corresponds to head, lower arms, hands, lower legs, and feet.
- ^b Fractional intake of 1 will be used to be consistent with EPA direction for seafood consumption scenarios.
- ^c Exposure frequency requested by Muckleshoot and Suquamish Tribes (Kissinger 2007b).
- ^d Exposure duration requested by Muckleshoot and Suquamish Tribes (Kissinger 2007b).

dw – dry weight

EPA – Environmental Protection Agency

na – not applicable

TBD – to be determined

3.3.2.1 Dermal adherence factor

The potential for sediment to adhere to skin has not been well characterized. Data for AFs for marine sediments, such as those found in the LDW, are extremely limited. A range of adherence factors exist for various soil conditions, including wet soils. Kissel et al. (1996) showed that soil adherence typically increases with increasing moisture content. Although current EPA (2004b) guidelines address the increase in soil adherence factors associated with moisture present in soil or sediment, more recent research suggests that the actual marine sediment adherence factors may be higher than those derived by EPA for wet soil (Shoaf et al. 2005a, b). The level of adherence directly affects dermal exposure estimates. As sediment loading increases, the fraction of chemical that adheres to the skin and is available to be absorbed will remain constant until all of the skin is covered by a thin layer of soil (known as the mono-layer) (Duff and Kissel 1996). Once this mono-layer threshold is crossed, the fraction of chemical that can be absorbed will decrease, inasmuch as not all of the soil is in constant, direct contact with skin. Both the amount of soil required to form the mono-layer and the associated adherence capability of the soil depend on grain size. Generally, larger particles will have a lower adherence factor than smaller particles. However, as previously mentioned, wet marine sediments are generally expected to have higher adherence capabilities than similarly composed dry soil. For the purposes of this risk assessment, a value of 0.2 mg/cm²-event (EPA 2004b) will be used in all risk calculations for all the clamming scenarios, the habitat restoration scenario, and the RME netfishing scenario. A lower adherence factor (0.02 mg/cm²-event) (EPA 2004b) will be used for the netfishing CT scenario. These are same values as those used in the LDW HHRA (Windward 2007c).

3.3.2.2 Dermal absorption fraction

The dermal absorption fraction (ABS) refers to the fraction of the chemical in sediment applied to the skin surface that is absorbed into the bloodstream. Many studies have focused on this topic, but there is considerable uncertainty regarding chemical-specific values (EPA 1992). EPA (2004b) has developed supplemental guidance for dermal risk assessment that provides ABS values for many organic chemicals but provides ABS values for only two metal COPCs, arsenic and cadmium (Table 3-34). The guidance document states that speciation of inorganic substances is crucial to estimating dermal absorption and data are insufficient to derive default values for other inorganic substances. Older EPA guidance (EPA 2001) on dermal absorption provided a general value of 0.01 for all metals, reflecting a generally low dermal absorption of metals. Because specific absorption values are not provided, the dermal absorption pathway was not evaluated quantitatively for metals without dermal absorption fractions. This approach is suggested in EPA (2004b), with values supplied in Exhibit 3-4 of that document.

Table 3-34. Dermal absorption fractions

Chemical	ABS (unitless)	Oral Absorption Adjustment ^a
2,3,7,8-TCDD TEQ	0.03	None
4,6-Dinitro-o-cresol ^b	0.1	None
Aluminum	None	None
Antimony	None	RfD × 0.15
Arsenic	0.03	None
Barium	None	RfD × 0.07
Benzidine ^b	0.1	None
Bis(2-chloroethyl) ether ^b	0.1	None
Cadmium	0.001	RfD × 0.025 (diet and solids)
cPAHs	0.13	None
Chromium	None	RfD × 0.025
Copper	None	None
Total DDTs	0.03	None
Dieldrin ^c	0.1	None
Dioxin/furan TEQ	0.03	None
Iron	None	None
Lead	None	None
Manganese	None	RfD × 0.04
Mercury	None	RfD × 0.07
Molybdenum	None	None
n-Nitrosodimethylamine ^b	0.1	None
n-Nitroso-di-n-propylamine ^b	0.1	None
Total PCBs	0.14	None
PCB TEQ	0.14	None
Silver	None	RfD × 0.04
Thallium	None	None
Toxaphene ^c	0.1	None
Vanadium	None	RfD × 0.026
Zinc	None	None

Source: RAGS Part E (EPA 2004b)

^a The oral adjustment values are presented in Exhibit 4-1 of EPA (2004b).

^b The ABS value for semivolatile organic compounds is 0.1, as recommended in EPA (2004b).

^c The ABS value for these organochlorine pesticides is the default value for semivolatile organic compounds, as recommended in EPA (2004b).

ABS – dermal absorption fraction

RfD – reference dose

cPAH – carcinogenic polycyclic aromatic hydrocarbon

TCDD – tetrachlorodibenzo-*p*-dioxin

EPA – US Environmental Protection Agency

TEQ – toxic equivalent

PCB – polychlorinated biphenyl

The toxicological benchmarks discussed in Section 4 are based on orally administered doses, which are not necessarily equivalent to dermally absorbed doses because of incomplete oral and or dermal absorption. Although a summary of gastrointestinal

absorption data for many chemicals is provided in Exhibit 4-1 of EPA (2004b), data are not available for all chemicals evaluated. In the case of organic chemicals to be evaluated in this HHRA, absorption via the oral route is greater than 50%. In these instances, EPA (2004b) recommends that no conversion of the oral toxicity value is needed. Thus, for this HHRA, a gastrointestinal absorption factor of 1 will be used for organic chemicals (i.e., oral toxicological benchmarks will be applied without modification).

Reference doses (RfDs) are lower when based on an absorbed rather than ingested dose. The oral absorption adjustment (see Table 3-36) is intended to reflect the internal dose resulting in the observed effect to be consistent with the estimation of the dermally absorbed exposure. The oral adjustment for RfDs is $RfD \times \text{gastrointestinal (GI) fraction absorbed}$. Currently, EPA does not recommend an absorption adjustment for any chemical with a carcinogenic mode of action.

For the EW HHRA, cadmium will likely be the only chemical with both a recommended dermal absorption factor and reduced oral absorption; thus, an adjustment to the cadmium RfD will be made for the analysis of the dermal exposure route. For cadmium, the adjustment factor shown in Table 3-36 will be applied to the oral RfD. The lower RfD for the internal dose (i.e., absorbed dose) reflects the incomplete absorption of cadmium in the oral study used to generate the RfD. For other metals lacking an ABS factor, no dermal absorption will be assumed for the risk characterization; therefore, the RfD adjustment is not relevant. The approach presented in this section is consistent with that used in the LDW HHRA (Windward 2007c).

3.3.3 Water exposure parameters

As part of the HHRA, risks to humans will be assessed based on exposure to chemical concentrations while swimming in East Waterway. As discussed in Section 3.1.1, because of the limited public access and high shipping traffic in the EW now and expected in the future, opportunities for swimming in the EW are and will be limited. The swimming exposure scenario evaluated will include dermal absorption and incidental ingestion of water, as might occur when swimming from a boat or jumping or falling off a dock. This exposure scenario will be evaluated for adults only and the exposure unit is the entire EW study area.

This section discusses the methods that will be used to calculate the chronic daily intake rates associated with this exposure pathway and presents the values used to parameterize this scenario. The parameters of the swimming scenario for incidental ingestion and dermal exposure to water are summarized in Tables 3-35 and 3-36. These parameters are generally based on the adult swimming from boat scenarios presented in the *King County Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay* (King County 1999), as agreed upon for application to the EW in the *Quality Assurance Project Plan: Surface Water Collection and Chemical Analysis* (Windward 2009b). Results from the King County assessment for the LDW were used to approximate swimming exposures and risks in the LDW HHRA (Windward 2007c).

Table 3-35. Daily intake calculations – incidental ingestion of water during adult swimming scenario (water exposure only)

Scenario timeframe: Current/future Medium: Water Exposure medium: Water Exposure route: Ingestion (incidental) Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = $EPC \times IR-w \times t_{event} \times EV \times EF \times ED \times CF \times 1/BW-a \times 1/AT$				
Parameter Code	Parameter Definition	Units	High Value ^a	Rationale/Reference
EPC	exposure point concentration in water	mg/cm ₂	TBD	Section 3.3.4
IR-w	Incidental ingestion rate	mL/hr	75	EPA (1991)
t _{event}	event duration	hrs/event	2.6	EPA (1988); BPJ
EV	event frequency	events/day	1	BPJ
EF	exposure frequency	days/yr	24	EPA (1997); BPJ
ED	exposure duration	Years	70	consistency with other scenarios in EW HHRA
CF	conversion factor	L/mL	0.001	na
BW-a	body weight – adult	Kg	71.8 ^c	EPA (1997)
AT-C	averaging time – cancer	Days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	Days	25,550	EPA (1989)

Source: Standard Table 4 in EPA (1998)

^a A low, medium, and high exposure value was analyzed by King County in the *King County Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay* (1999). Table 3-40 presents the low, medium, and high values, but only the high values are shown here.

^b Fractional intake of 1 will be used to be consistent with EPA direction for seafood consumption scenarios.

^c Mean body weight for male and female adults from Table 7-2 in EPA (1997).

BPJ – best professional judgment

EPA – US Environmental Protection Agency

na – not applicable

TBD – to be determined

Table 3-36. Daily intake calculations –dermal exposure to water during adult swimming scenario (water exposure only)

Scenario timeframe: Current/future Medium: Water Exposure medium: Water Exposure route: Dermal Intake equation/model name: Chronic daily intake (CDI) (mg/kg-day) = $DA_{event} \times SA_w \times t_{event} \times EV \times EF \times ED \times 1/BW-a \times 1/AT$				
Parameter Code	Parameter Definition	Units	High Value ^A	Rationale/Reference
DA _{event}	dermally absorbed dose per event	mg/cm ² -event	TBD	Section 3.3.3.1
SA _w	skin surface area exposed	cm ²	21,800	EPA (1991)
t _{event}	event duration	hrs/event	2.6	EPA (1988); BPJ
EV	event frequency	events/day	1	BPJ
EF	exposure frequency	days/yr	24	EPA (1997); BPJ
ED	exposure duration	years	70	consistency with other scenarios in EW HHRA
BW-a	body weight – adult	Kg	71.8 ^c	EPA (1997)
AT-C	averaging time – cancer	Days	25,550	EPA (1989)
AT-N	averaging time – non-cancer	Days	25,550	EPA (1989)

Source: Standard Table 4 in EPA (1998)

^a A low, medium, and high exposure value was analyzed by King County in the *King County Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay* (1999). Table 3-40 presents the low, medium, and high values, but only the high values are shown here.

^b Fractional intake of 1 will be used to be consistent with EPA direction for seafood consumption scenarios.

^c Mean body weight for male and female adults from Table 7-2 in EPA (1997).

BPJ – best professional judgment

EPA – Environmental Protection Agency

na – not applicable

TBD – to be determined

3.3.3.1 Dermal exposure to water

Dermal exposure to chemical concentrations in water (e.g., while swimming or wading) are calculated as shown in Equation 3-4 (EPA 2004b):

$$CDI = \frac{DA_{\text{event}} \times t_{\text{event}} \times EV \times EF \times ED \times SA_w}{BW \times AT} \quad \text{Equation 3-4}$$

Where:

CDI	=	chronic daily intake rate, dermally absorbed dose (mg/kg-day)
DA _{event}	=	absorbed dose per event (mg/cm ² -event)
t _{event}	=	event duration (hours/event)
EV	=	event frequency (events/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
SA _w	=	skin surface area (cm ²)
BW	=	body weight (kg)
AT	=	averaging time (cancer or non-cancer) (days)

The absorbed dose per event (DA_{event}) is calculated differently for organic and inorganic compounds based on the different absorption properties of these chemicals.

Equation 3-5 presents the approach for calculating the absorbed dose per event for inorganic chemicals (EPA 2004b):

$$DA_{\text{event}} = K_p \times C_w \times t_{\text{event}} \quad \text{Equation 3-5}$$

Where:

DA _{event}	=	Absorbed dose per event (mg/cm ² -event)
K _p	=	chemical-specific dermal permeability coefficient of compound in water (cm/hour)
C _w	=	Chemical concentration in water (mg/cm ³)
t _{event}	=	event duration (hours/event)

For organic chemicals, depending on whether the time needed to reach steady state with regard to absorption through the skin is greater or less than the event duration, a different equation is required to calculate dose per event. Equations 3-6 and 3-7 present the two approaches for calculating the absorbed dose per event for organic chemicals (EPA 2004b):

If $t_{\text{event}} \leq t^*$, then Equation 3-6 should be used:

$$DA_{\text{event}} = 2 \times FA \times K_p \times C_w \times \sqrt{\frac{6 \times \tau_{\text{event}} \times t_{\text{event}}}{\pi}} \quad \text{Equation 3-6}$$

If $t_{\text{event}} > t^*$, then Equation 3-7 should be used:

$$DA_{\text{event}} = FA \times K_p \times C_w \times \left[\frac{t_{\text{event}}}{1+B} + 2 \times \tau_{\text{event}} \times \left(\frac{1+3B+3B^2}{(1+B)^2} \right) \right] \quad \text{Equation 3-7}$$

Where:

t_{event}	=	event duration (hours/event)
t^*	=	time to reach steady-state (hours)
DA_{event}	=	absorbed dose per event (mg/cm ² -event)
FA	=	chemical-specific fraction absorbed from water (unitless)
K_p	=	chemical-specific dermal permeability coefficient of compound in water (cm/hour)
C_w	=	chemical concentration in water (mg/cm ³)
τ_{event}	=	chemical-specific lag time per event (hr/event)
B	=	ratio of the permeability coefficient of a compound through the stratum corneum (one of two skin layers) relative to its permeability coefficient across the variable epidermis (one of two skin layers) (unitless)

3.3.3.2 Incidental ingestion of water

Exposure to chemical concentrations via the incidental ingestion of water while swimming is calculated as shown in Equation 3-8 (EPA 1989):

$$CDI = \frac{C_w \times IR_w \times t_{\text{event}} \times EV \times EF \times ED \times CF}{BW \times AT} \quad \text{Equation 3-8}$$

Where:

CDI	=	chronic daily intake rate, dermally absorbed dose (mg/kg-day)
C_w	=	chemical concentration in water (mg/cm ³)
IR_w	=	incidental water ingestion rate (ml/hr)
t_{event}	=	event duration (hrs/event)
EV	=	event frequency (events/day)
EF	=	exposure frequency (assume one event per day) (days/year)
ED	=	exposure duration (years)
CF	=	conversion factor (1 × 10 ⁻³) (L/mL)
BW	=	body weight (kg)
AT	=	averaging time (cancer or non-cancer) (days)

3.3.3.3 Exposure parameters

The swimming scenario will be parameterized using the values presented the *King County Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay* (King County 1999), as agreed upon for application to the EW in the *Quality Assurance Project Plan: Surface Water Collection and Chemical Analysis* (Windward 2009b).

Table 3-37 presents the general exposure parameters that will be used for the swimming scenarios. Table 3-38 presents the site-specific swimming scenario parameters. Note that the King County assessment used a range of body weights ranging from 60 to 79 kg. A

body weight of 71.8 kg (EPA 1997) will be used for low, medium, and high swimming scenarios so that these can be combined with risk estimates for other scenarios that used this same body weight (e.g., habitat restoration worker and 7-day-per-year clamming). In addition, Table 3-40 presents low, medium, and high exposure scenarios that will be evaluated for different frequencies and durations. The assumed exposure duration for the high-level exposure scenario was reduced from 75 years in the King County assessment to 70 years, and the assumed exposure duration for the medium-level exposure scenario was reduced from 33 years in the King County assessment to 30 years to be consistent with other scenarios being evaluated in this risk assessment. The average times for cancer risk assessment were similarly adjusted. For non-cancer hazard estimates for all levels of exposure, the averaging time will be equal to the exposure duration. The values for chemical-specific parameters are not presented here but will be compiled in the HHRA for COPCs.

Table 3-37. Summary of general swimming exposure parameters and values

Exposure Parameter	Symbol	Unit	Value	Source
Averaging time, carcinogenic	AT_{cancer}	days	70 yrs x 365 d/yr	EPA (2004b, 1989)
Averaging time, non-carcinogenic	$AT_{noncancer}$	days	ED x 365 d/yr	EPA (2004b, 1989)
Dermal permeability coefficient of compound in water	K_p	cm/hour	chemical-specific	EPA (2004b), Exhibit B-3
Time to reach steady-state	t^*	hours	$\tau_{event} \times 2.4$	EPA (2004b)
Chemical-specific lag time per event	τ_{event}	hr/event	chemical-specific	EPA (2004b), Exhibit B-3
Chemical-specific fraction absorbed from water	FA	unitless	chemical-specific	EPA (2004b), Exhibit B-3
Chemical-specific dermal permeability coefficient of compound in water	K_p	cm/hour	chemical-specific	EPA (2004b), Exhibit B-3
Ratio of the permeability coefficient of a compound through the stratum corneum ^a relative to its permeability coefficient across the variable epidermis ^a	B	unitless	chemical-specific	EPA (2004b), Exhibit B-3
Chemical-specific dermal absorption fraction	ABS_d	fraction	chemical-specific	EPA (2004b), Exhibit 3-4

^a The stratum corneum and variable epidermis are the main two layers of skin. The stratum corneum is the main barrier preventing the absorption of chemicals.

EPA – US Environmental Protection Agency

Table 3-38. Summary of adult swimming scenario exposure parameters

Exposure Parameter	Symbol	Unit	Exposure Level			Source ^a
			Low	Medium	High	
Event duration	t_{event}	hrs/event	0.17	1	2.6	EPA (1988); BPJ
Event frequency	EV	events/day	1	1	1	BPJ
Exposure frequency	EF	days/yr	2	12	24	EPA (1997); BPJ
Exposure duration ^b	ED	years	9	30	70	EPA (1991), consistency with other scenarios in EW HHRA
Body weight ^c	BW	kg	71.8	71.8	71.8	EPA (1997)
Skin surface area exposed to water	SA_w	cm ²	4,900	19,400	21,800	EPA (1991)
Incidental water ingestion rate	IR_w	ml/hr	25	50	70	EPA (1991), consistency with other scenarios in EW HHRA

^a As cited in King County (1999), except as noted for body weight and exposure duration.

^b Exposure duration for high-level exposure scenario was reduced from 75 years in the King County (1999) assessment to 70 years, and exposure duration for medium-level exposure scenario was reduced from 33 years in the King County (1999) assessment to 30 years to be consistent with other scenarios evaluated in this risk assessment.

^c Mean body weight for male and female adults from Table 7-2 in EPA (1997).

BPJ – best professional judgment

EPA – US Environmental Protection Agency

3.3.4 Exposure point concentrations

An EPC will be calculated for each seafood consumption category, sediment exposure area, and the EW water exposure area. Figure 3-3 shows the methods used to estimate EPCs based on the number of detected concentrations present in a given dataset. Based on the COPC identification process, some chemicals may be identified as COPCs even if they are never detected (i.e., if they have > 10% of reporting limits exceeding the RBC). Chemicals that are not detected in a particular media (water, sediment, or tissue) will be evaluated qualitatively in the uncertainty analysis for the appropriate pathways. However, if a chemical is detected and designated as a COPC for any seafood tissue type, EPCs will be developed for the other tissue types so that market basket seafood exposure can be evaluated in the risk characterization section. Hence, EPCs will be developed for some datasets for which there are no detected values.

No. of Detected Values	Method for Selecting EPC
0	→ Use one-half of the maximum reporting limit.
1 – 5	→ Select the higher of one-half the maximum reporting limit OR the maximum detected value.
6 or more	→ Use ProUCL 4.0, indicating detected and undetected values.

Figure 3-3. Flow chart showing method for selecting EPC

A flowchart for selecting or calculating the appropriate EPC value is provided in Figure 3-3. The primary consideration in this step will be the number of detected values available for a particular chemical and exposure area. The ProUCL software to be used for this analysis allows detected and undetected values to be indicated and creates interpolated values for non-detects based on the perceived distribution of the detected concentrations. This method is an improvement over older versions of ProUCL, which had no provision for handling undetected values. Once any necessary interpolation is performed, the software conducts an analysis of the data to determine the most appropriate UCL and makes a recommendation.

As stated previously, the rationale for selecting EPCs will be based largely on the detection frequency for each chemical. The approach to calculate EPCs that is outlined above is intended to use all available data, be statistically defensible where possible, and adopt health-protective policies for deriving EPCs when statistical approaches for computing 95% UCLs are not available. This approach is also consistent with EPC calculation for the LDW HHRA (Windward 2007c). When fewer than six detected concentrations are available, the higher of either the maximum detected concentration or one-half the maximum RL will be selected as the EPC. This approach was selected because 95% UCLs on the mean (95UCL) calculated from datasets with very few detected concentrations are not expected to be reliable enough for deriving EPCs. Chemical contamination datasets are often positively skewed. For such positively skewed datasets, the true mean is greater than the 50th percentile and can be substantially greater when skewness is large. When the number of samples used to characterize an exposure area is very small (e.g., $n < 6$), there is a significant probability that the maximum result among those few samples will be less than the true mean. Even when using an approach that assigns the maximum sample result as an EPC value, there is still a risk of underestimating exposures. This uncertainty is unavoidable when only a few samples are available to characterize an exposure area.

Certain classes of compounds are made up of individual compounds that have similar chemical structures as well as a common mechanism of toxicity. Exposure and toxicity are assessed for these classes on a group rather than on an individual compound basis. These compound groups include co-planar PCBs, chlorinated dioxins/furans and cPAHs. The methods for calculating totals (including PCB TEQ, dioxin/furan TEQ, and cPAH totals) on a sample-by-sample basis are briefly summarized here. The sum of the products of the concentration of each coplanar PCB and its TEF is called the PCB TEQ and is calculated on a per sample basis. Similarly, the sum of the products of each coplanar dioxin and furan and its TEF is called the dioxin/furan TEQ and is also calculated on a per sample basis. The sum of the products of the concentration of each cPAH and its PEF is considered the cPAH total and is calculated on a per sample basis. Once the TEQs for PCBs, dioxin/furans, and total cPAHs are calculated on a per sample basis, the methods for calculating the EPC for each of those is the same as that for other chemicals. Summary statistics, the distribution type, and the UCL for chemical concentrations in tissue for all seafood consumption categories, sediment exposure areas, and water will be presented in HHRA. The methods for calculating the EPCs for tissue and sediment are described in detail in the following subsections.

3.3.4.1 Tissue

Based on the seafood consumption surveys summarized in Section 3.3.1, 10 consumption categories based on seafood types were identified. Table 3-39 lists the species for which tissue data will be included to develop EPCs for each of the categories.

Table 3-39. Seafood consumption categories for developing EPCs

Seafood Category	EW Species and Tissue Types Included for Tissue Data
Benthic fish, fillet	English sole, skin-on and skinless fillet
Benthic fish, whole body	English sole, whole body and skin-on or skinless fillet and remainder ^a
Pelagic fish, rockfish	Rockfish
Pelagic fish, perch ^b	shiner surfperch, whole body; striped perch, fillet
Crab, edible meat	Dungeness and red rock crab
Crab, whole body ^c	Dungeness and red rock crab
Clams ^d	all intertidal clams (butter clams, littleneck clams, cockles, and softshell clams)
Mussels	bay mussel
Geoduck clams, edible meat	Geoducks
Geoduck clams, whole body ^e	Geoduck, edible meat and gut ball

^a The results for the fillet composite samples and the remainder composite samples will be weighted based on the fraction of the whole-body mass represented by each sample in order to calculate whole-body results (Windward 2006) (see Table 2-2 for more details).

^b Whole-body and fillet data will be treated together for the calculation of one EPC. Seafood consumption surveys indicate people eat both whole-body and filleted pelagic fish. However, because there are no fillet and

whole-body data available for the same species (allowing for apportionment of fillet and whole-body consumption), these data will be treated together as a single pelagic fish category.

- ^c Data from hepatopancreas composite samples will be mathematically combined with data from composite samples of edible meat to form composite samples of edible meat plus hepatopancreas. Whole-body (i.e., edible meat plus hepatopancreas) crab concentrations will be calculated using the relative weights and concentrations of the edible meat and hepatopancreas.
- ^d EPCs based on all clams collected from intertidal areas (regardless of species) will be used for clam exposure estimates.
- ^e Data from gut ball composite samples will be mathematically combined with data from composite samples of edible meat to form composite samples of edible meat plus gut ball. Whole-body (i.e., edible meat plus gut ball) geoduck concentrations will be calculated using the relative weights and concentrations of the edible meat and gut ball.

API – Asian and Pacific Islander

EPC – exposure point concentration

The decision to compute overall intertidal bivalve EPCs without considering species specific EPC differences was made after it was determined that approaches that did and did not consider species specific EPC differences caused little variation in overall bivalve EPCs. Given the high level of uncertainty in how to apportion consumption of multiple intertidal bivalve species at a specific site, it is important to consider how the concentrations of different contaminants vary across species present prior to selecting an apportionment method. In addition, unlike the other apportionment methods evaluated, using one UCL inclusive of all intertidal clam samples does not assume a specific distribution of different species will be collected repeatedly. Instead it is a UCL for the mixture of intertidal clams actually collected in EW; the abundance of different clam species in EW is not well understood but may differ from the assemblage of clams available in other areas of Puget Sound. Selection of this approach is specific to the EW and does not imply a precedent for selection of shellfish apportionment methods at other sites.

EPC values will be determined for each seafood category using the datasets described in Section 2.2. EPCs for the entire EW will be calculated for each seafood category in Table 3-41 as is appropriate for the assumptions of the exposure scenarios and the size of the EW (i.e., exposure for subareas of the EW will not be evaluated).

3.3.4.2 Sediment

The netfishing exposure scenarios will include all relevant intertidal and subtidal surface sediment samples in the EW from the dataset described in Section 2.1. As described briefly in the Section 2.1, subtidal and intertidal exposures will be calculated separately and then combined to estimate study area-wide concentrations. For all chemicals except dioxin/furan TEQ and PCB TEQ, all appropriate subtidal samples (except the 13 composite grab samples) will be used to develop a subtidal EPC (i.e., the 95% UCL of these samples), and the three intertidal-wide MIS samples will be used to develop the EPC for the intertidal area. The final method for determining the EPCs for the intertidal MIS samples has not yet been determined. The method for calculation of the intertidal MIS EPC will be resolved through discussions with EPA prior to completion of the draft HHRA. The subtidal and intertidal EPCs will then be weighted

based on the size of their relative areas to estimate a study area-wide EPC for the netfishing scenarios.

A slightly different approach will be used for dioxin/furan TEQ and PCB TEQ netfishing EPCs. For estimating TEQs for the netfishing scenarios, the EPC for the subtidal area will be calculated using the 13 grab composite samples, and the EPC for the intertidal area will be calculated using the three intertidal-wide MIS samples. The EPC for the subtidal composites will be the 95% UCL of these samples, and the EPC approach for the intertidal MIS samples has not yet been determined but will be developed using the three intertidal MIS samples. As will be done for other chemicals, these two EPCs will then be weighted based on the relative area of the intertidal and subtidal regions to develop study area-wide EPCs for dioxin/furan TEQ and PCB TEQ for the netfishing scenarios.

The EPCs for the tribal clamming and habitat restoration scenarios (for all chemicals) will be determined using the three MIS samples representing study area-wide intertidal-wide exposure. As discussed previously, the exact method has not yet been determined. The intertidal locations of the EW relevant for these scenarios are indicated on Map 3-1. The EPCs for the clamming 7-day-per-year scenario will be derived using the single MIS for the intertidal areas that are publically accessible by walking (see Map 3-1). Again the exact method for calculation of these EPCs will be determined through discussions with EPA prior to completion of the draft HHRA. For areas where no sediment can be collected (because the substrate in those areas is gravel, cobble, or riprap), exposure to sediment cannot be assessed.

3.3.4.3 Water

The available water datasets were described in Section 2.3. Historical (see Table 2-3) and all recently collected (i.e., 2008-2009 data) water data collected 1 m from the surface (Windward 2009b) will be evaluated for data usability. Data from 2008-2009 samples collected 1 m from the bottom will not be included because people would not be expected to swim at those depths. All acceptable data will be included for the calculation of water EPCs for use in the evaluation of the swimming scenario.

3.3.5 Lead modeling

Risk estimates from lead exposure will not be made not made using the equations presented in Section 3.3. Instead, risks will be estimated using the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) (EPA 1994) and the Adult Lead Model (ALM) (EPA 2003b). The parameterization of each model is discussed in the subsections below.

3.3.5.1 Children (IEUBK)

The IEUBK model (Version 1.0 for Windows®) predicts blood-lead concentrations for children exposed to lead in their environment. The model requires input such as relevant absorption parameters and intake and exposure rates. The model then

calculates and recalculates a complex set of equations to estimate the potential concentration of lead in the blood for a hypothetical population of children (aged 6 months to 7 years).

Default input parameters exist in the model for lead intake via air, drinking water, and diet. The IEUBK model allows for alternate dietary data to be used if data are available. If site-specific data are available, they are used to calculate the lead concentration for the alternate dietary source and the percentage of total dietary input that is represented by the alternate dietary source. The alternate dietary data are added to the other source data to derive a combined intake from all sources. For this HHRA, all default parameters recommended for use in the model by EPA will be maintained except for alternate dietary source. The model pre-set value of 200 mg/kg dw will be used for the soil concentration, which represents a “plausible value for urban soil lead concentration” (EPA 2002c). This value was not modified because no child specific sediment exposure scenario is being evaluated for EW. The model may be run with different assumptions of lead soil concentration to evaluate the sensitivity of the model to this parameter.

The default values for diet vary from 2.60 to 3.16 µg/day. These values are used to determine dietary lead exposure, unless data describing an alternate dietary source are entered. The alternate sources may include data for fish from fishing, home grown fruits and vegetables, and game animals from hunting. The model requires input on both the concentration of lead in the alternate dietary sources as well as the proportion of total dietary intake these categories represent (the default concentration for all replacement foods = 0 mg/kg, default percentage of all food consumed = 0%). For the EW, only the fish from fishing category was adjusted, because data for other food-borne sources of lead are not available. Table 3-40 presents the alternate food source lead concentration due to fish from fishing as well as the proportion of dietary intake represented by fish.

Table 3-40. Input parameters for IEUBK lead model

Parameter	Value	Unit	Exposure Frequency
Alternate food source concentration ^a	TBD	µg Pb/g	365 days per year
Alternate food source fraction ^b	12	%	na

^a Alternate food source concentration will be derived as a single value for all seafood categories by weighting the concentration in each seafood category by the amount of that category that is consumed. This calculation will use the seafood tissue mean concentrations and the median child seafood consumption rates for each category. The alternate food source concentration will be determined by summing the product of the mean EPC x ingestion rate for each seafood category and then dividing that total by the sum of the ingestion rates for each seafood category. Median values for ingestion rates will be used per IEUBK model use guidelines (EPA 1994).

^b 12 g/day (average amount of Puget Sound seafood consumed per day)/98.05 g/day (total meat consumed per day) (EPA 2006).

dw – dry weight

Pb – lead

EPC – exposure point concentration

TBD – to be determined

IEUBK – Integrated Exposure Uptake Biokinetic Model for Lead in Children

ww – wet weight

na – not applicable

Alternate dietary data from the child tribal scenario based on Tulalip data for the consumption of fish and shellfish will be included in the model. The IEUBK model applies average or CT estimates for all terms (EPA 1994). For seafood consumption rates, the median child seafood consumption rate was identified based on 40% of the median adult tribal seafood consumption rate based on Tulalip data of 29.9 g/day (EPA 2006). Furthermore, the percentage of the alternate food source (fish) of its food group (all meat) will be set at 12%. In order to calculate the average food lead concentration in the variety of fish consumed by tribal children, the median ingestion rate will be multiplied by the mean lead concentration for each seafood category. Consistent with the LDW HHRA (Windward 2007c), anadromous fish will be included in the seafood consumption rate for children in the IEUBK model. Lead concentration in anadromous fish will be estimated based on data collected by the Puget Sound Ambient Monitoring Program (PSAMP) (West et al. 2001). The sum of the results of this calculation will then be divided by the total ingestion rate to get the average lead concentration for EW fish.

3.3.5.2 Adults (ALM)

The ALM is based on protecting the developing fetus of a pregnant woman, the most sensitive subpopulation affected by adult lead exposure. The model incorporates exposure to soil that is more representative of older children and adults than young children. Accordingly, EPA has used this model to estimate soil lead cleanup levels for sites at which the likely exposed population would be older children or adults.

Although the model was developed to assess soil exposures, it will be applied in the EW, consistent with its application to the LDW (Windward 2007c), to evaluate exposure to lead in both sediments and in fish and shellfish. Adjustments were made to the model to account for fish intake (EPA 2007c). Specifically, Kissinger (2002) provided a revised algorithm that incorporates an exposure term for seafood consumption. This approach provides a way to evaluate cumulative exposure to lead in the EW from both

dermal soil contact and seafood ingestion while still using the ALM spreadsheets developed by EPA.

The ALM applied for the EW estimates an average blood lead level in adults based on additional exposure (above a baseline level) to lead in sediments, seafood, and air. An estimated fetal blood lead level is then calculated from the estimated adult blood lead levels (Equation 3-9. The contribution of lead from air at the EW site was considered negligible because blood lead levels are much less sensitive to passive re-entrainment of lead from soil in air. The equation is thus:

$$PbB_{\text{adult,central}} = \frac{PbB_0 + BKSF \times FI \times ((Pb_s \times IR_s \times AF_s \times EF_s) + (Pb_f \times IR_f \times AF_f \times EF_f))}{AT} \quad \text{Equation 3-9}$$

where $PbB_{\text{adult,central}}$ is the geometric mean blood lead level ($\mu\text{g}/\text{dL}$) in exposed adults. The definition and parameterization of the other variables in the equation above are provided in Table 3-43.

Table 3-41. Input parameters for ALM

Parameter	Description	Value	Unit
PbB_0	adult baseline (geometric mean) blood lead level	1.53 ^a	$\mu\text{g}/\text{dL}$
BKSF	biokinetic slope factor	0.4 (EPA default)	$\mu\text{g}/\text{dL}$ per $\mu\text{g}/\text{day}$
FI	fractional intake	1	unitless
IR_s	sediment ingestion rate –netfishing	50 (EPA default) ^b	mg/day
IR_s	sediment ingestion rate – clamming	100 (EPA default) ^b	mg/day
IR_f	seafood ingestion rate	15 ^c	g/day
Pb_s	mean lead concentration in sediment – tribal clamming RME	TBD	mg/kg dw
Pb_s	mean lead concentration in sediment – netfishing	TBD	mg/kg dw
EF_s	exposure frequency for tribal clamming RME	120	days/yr
EF_s	exposure frequency for netfishing	119	days/yr
Pb_f	lead concentration in seafood	TBD ^d	mg/kg ww
EF_f	exposure frequency for seafood consumption	365	days/yr
AF_s	gastrointestinal absorbance fraction for lead in sediment	0.12 (EPA default for soil) ^e	unitless
AF_f	gastrointestinal absorbance fraction for lead in tissue	0.12 ^f	unitless
AT	averaging time	365	days

^a The average baseline blood lead level of women in the US will be used (EPA 2002a).

^b Although EPA has not developed default exposure assumptions for sediments, a conservative assumption will be applied that assumes sediment consumption would be equivalent to 100% of the assumed soil and dust intake on each day an individual visits the EW.

^c Median Puget Sound seafood consumption rate (Hiltner 2007). The median resident fish consumption rate was developed by taking the median Tulalip Tribes' fish consumption rate for all species harvested from Puget Sound, 29.9 g/day, and adjusting it to represent consumption of resident species only. This approach was also used for the LDW and is explained in detail in the LDW HHRA (Windward 2007c).

- ^d Lead concentration in seafood equals the sum of (mean lead concentration × ingestion rate) for each seafood category/total IR
- ^e Gastrointestinal absorption fraction for lead in sediment (EPA 2003b).
- ^f Gastrointestinal absorption fraction for lead in tissue (EPA 2007c).

ALM – Adult Lead Model

dw – dry weight

EPA – US Environmental Protection Agency

LDW – Lower Duwamish Waterway

TBD– to be determined

ww – wet weight

Lead EPC values will be calculated for tissue and sediment based on the 95th UCL as will be done for all other chemicals evaluated in the HHRA. However, because the ALM guidelines (EPA 2003b) recommend using mean sediment and tissue values for calculating risks from lead exposure, mean values will be calculated and applied in the ALM. Median ingestion rates will be calculated for use in the ALM to assess risks from the ingestion of fish tissue containing lead. In order to illustrate the range of risks to adults exposed to lead in the EW, exposure scenarios including the adult RME clamming and netfishing sediment exposure scenarios will both be evaluated (using the 95th UCL exposure estimates).

The adult tribal CT ingestion rate based on Tulalip data (Hiltner 2007) will be used in the lead model because EPA guidance calls for use of median ingestion rates in the ALM (see Section 3.3.1.1 for additional discussion of these ingestion rates). The adult Tulalip CT ingestion rates will be combined with the mean lead concentrations for each seafood category to calculate a weighted average lead concentration for all seafood. Anadromous fish consumption will not specifically be addressed in the tissue lead calculations because it is considered to be part of baseline dietary exposure, which is included in the baseline blood lead level.

The model output includes both CT (geometric mean) and 95th percentile fetal blood lead levels. The 95th percentile fetal blood lead level is calculated using Equation 3-10:

$$\text{PbB}_{\text{fetal95}} = \text{PbB}_{\text{adult,central}} \times \text{GSD}_{\text{i,adult}}^{1.645} \times \text{R}_{\text{fetal/maternal}} \quad \text{Equation 3-10}$$

Where:

$\text{PbB}_{\text{fetal95}}$	=	95 th percentile fetal blood lead level (µg/dL)
$\text{PbB}_{\text{adult,central}}$	=	central estimate of maternal adult blood lead concentration
$\text{GSD}_{\text{i,adult}}$	=	geometric standard deviation of the blood lead distribution
1.645	=	95 th percentile value for the Student's t distribution
$\text{R}_{\text{fetal/maternal}}$	=	proportionality constant between fetal and maternal blood lead concentration

The geometric standard deviation (GSD) is an estimation of variation in blood lead levels around the geometric mean. It is used to estimate upper percentile blood lead levels for an individual and provide a health-protective estimate of the probability of an individual exceeding a given blood lead level (target risk goal). In accordance with EPA

(2002a), a GSD of 2.29 was applied to this model. Fetal blood lead levels will be predicted based on the EPA assumption that fetal blood lead levels at birth are 90% of the maternal blood lead level. A 10 µg/dL blood lead level for a fetus is associated with a 11.1 µg/dL blood lead level for the mother according to EPA (2003b). The probability of exceeding the 10-µg/dL blood lead threshold for an individual will be calculated using the following mathematical function in Microsoft® Excel®:

$$P_{\text{exceedance}} = 1 - \text{Normdist}(\ln(\text{Pb}_{\text{target}}/\text{Pb}_{\text{central}} \times R_{\text{fetal/maternal}})) / \ln(\text{GSD})) \quad \text{Equation 3-11}$$

Where:

$\text{Pb}_{\text{target}}$	=	child threshold blood lead level (in this application, 10 µg/dL)
$\text{Pb}_{\text{central}}$	=	child central tendency blood lead estimate
$R_{\text{fetal/maternal}}$	=	proportionality constant between fetal and maternal blood lead concentration
GSD	=	geometric standard deviation of the blood lead distribution

4 Toxicity Value Selection Approach

The toxicity assessment is an evaluation of each chemical's potential to cause health effects based on available toxicological information.

Quantitative estimates of toxicity potential have been developed by EPA and other agencies. EPA (2003a) has developed a hierarchical order of toxicity values for use in human health risk assessments that will be applied for the development of toxicity values for COPCs for this risk assessment:

- ◆ **Tier 1** – EPA's Integrated Risk Information System (IRIS) database
- ◆ **Tier 2** – EPA's Provisional Peer-Reviewed Toxicity Values (PPRTVs), Office of Research and Development/National Center for Environmental Assessment
- ◆ **Tier 3** – Other toxicity values. Tier 3 includes additional EPA and non-EPA sources of toxicity information. Priority is given to those sources of information that are the most current, the basis for which is transparent and publicly available, and which have been peer reviewed. Sources include EPA regional offices, EPA Health Effects Assessment Summary Tables (HEAST) values, California EPA, and Agency for Toxic Substance and Disease Registry (ATSDR) minimal risk levels.

Chemicals may be quantitatively evaluated on the basis of their non-carcinogenic and/or carcinogenic potential. The toxicity values used for evaluating exposure to chemicals with non-carcinogenic and carcinogenic effects are called the reference dose (RfD) and slope factor (SF), respectively.

The RfD is an estimate, with uncertainty spanning perhaps an order of magnitude or greater, of the daily exposure of the human population, including sensitive sub-populations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. In developing toxicity values for non-cancer effects, EPA reviews available data to identify the most sensitive endpoint and population (i.e., the effects that occur at the lowest concentration). These available data include effects on children and other sensitive subpopulations. Chemicals may have additional adverse effects that occur at higher exposure levels.

The SF represents a plausible upper-bound estimate of the probability of a carcinogenic response per unit intake of a chemical over a lifetime. EPA has recently updated their guidance for carcinogen risk assessment to emphasize consideration of mode of action (e.g., mutagenesis) in the development of SFs (EPA 2005c). Generally, the SF is based on a dose-response curve using available carcinogenic data for a given chemical. Mathematical models are used to extrapolate from high experimental doses to the low doses expected for human contact in the environment. The selection of the mathematical model for dose extrapolation (e.g., linear or non-linear) should be informed by the mode of action of the chemical (EPA 2005c).

5 Calculation and Presentation of Risk Characterization Results

This section summarizes the approach for risk estimate calculations as well as the planned presentation of the risk estimates. Cancer and non-cancer risks will be calculated separately in a manner consistent with EPA guidance and the LDW HHRA. This includes implementation of EPA's recent guidance for children's carcinogenic risk assessment (EPA 2005d) consistent with the LDW HHRA (Windward 2007c). Excess cancer risks and HQs will be presented according to the format recommended in EPA (1998) for chemicals detected in EW sediment, seafood, or water. A general approach for the evaluation of background contributions to risk is also presented.

5.1 CALCULATION OF EXCESS CANCER RISKS

For relatively low probabilities (i.e., below 1 in 100), carcinogenic risks are calculated by multiplying the estimated exposure level (the chronic daily intake [CDI]) by the cancer SF for each chemical.¹¹

$$\text{Risk} = \text{CDI} \times \text{SF} \quad \text{Equation 5-1}$$

Where:

Risk = estimated chemical-specific individual excess¹² lifetime excess cancer risk (unitless)
CDI = chemical-specific chronic daily intake (mg/kg-day)
SF = route- and chemical-specific carcinogenic SF (mg/kg-day)⁻¹

A number of COPCs that are never detected may have RLs that exceed RBCs. Consistent with the LDW HHRA (Windward 2007c), hypothetical risk estimates from these undetected COPCs will be qualitatively evaluated and discussed in the uncertainty analysis. Risks estimates attributable to these undetected chemicals have very high uncertainty, and thus are not considered appropriate for identifying risks or locations where remediation might be warranted.

Excess cancer risks will be summed across chemicals for each exposure scenario. Consistent with the LDW HHRA (Windward 2007c), two risk estimate totals across chemicals will be presented, one including the all detected non-PCB chemicals and total PCB excess cancer risk (excluding PCB TEQ excess cancer risk), and the other including all detected non-PCB chemicals and PCB TEQ excess cancer risk (excluding total PCB excess cancer risk). PCB TEQ and dioxin/furan TEQ will also be subtotaled in the second approach to estimate total dioxin-like TEQ risk.

EPA has recently provided additional guidance for children's carcinogenic risk assessment (EPA 2005d), and Region 10 provided instructions on the implementation of this guidance for the LDW (EPA 2006). For cPAHs, which have been identified as having a mutagenic mode of action, dose estimates will be adjusted upwards in the risk calculation in the following manner to account for potential greater susceptibility of children from 0 to 6 years of age compared with older children and adults:

$$\text{cPAH risk ages 0 to 6} = \left[(\text{dose cPAH}_{\text{overall}} \times 2/6) \times 10 + (\text{dose cPAH}_{\text{overall}} \times 4/6) \times 3 \right] \times \text{cPAH SF} \quad \text{Equation 5-2}$$

¹¹ In cases where excess cancer risk estimates exceed 1 in 100, the exponential version of the risk equation will be used, as per EPA guidance (1989).

¹² Excess cancer risk refers to risks associated with site-specific exposure, above and beyond risks associated with exposure from all other causes, including exposure to carcinogenic sources outside the site.

For all exposure routes (i.e., ingestion of seafood or sediment and dermal contact with sediment), this dose adjustment will be made in the final risk calculation rather than as an adjustment to exposures or to carcinogenic potency. Implementation of this approach will result in approximately a five-fold increase in the cancer risk estimate for cPAHs for children and is based on the assumption that toxicity of carcinogens with a mutagenic mode of action could be greater for younger children than for older children or adults.

5.2 CALCULATION OF NON-CANCER HAZARDS

The potential for non-carcinogenic health effects is represented by the ratio of a chemical's exposure level and the route-specific RfD and is expressed as a hazard quotient (HQ):

$$\text{HQ} = \text{CDI}/\text{RfD} \quad \text{Equation 5-3}$$

Where:

- HQ = estimated chemical-specific hazard quotient (unitless)
- CDI = chemical-specific chronic daily intake (mg/kg-day)
- RfD = route- and chemical-specific reference dose (mg/kg-day)

The HQ is recommended by EPA as a way to quantify the potential for non-carcinogenic health effects (EPA 1989). HQs are not risk probabilities; the likelihood of an adverse effect does not usually increase linearly with the calculated value. An HQ greater than 1 indicates potential adverse health effects from the chemical exposure, although the same HQ may not equate to the same magnitude of adverse health effects for all chemicals. HQ interpretation considers the shape and slope of the dose-response curve in the area of observation, the magnitude of uncertainty and modifying factors to the RfD, and the confidence assigned to the RfD by EPA.

Individual COPCs with similar toxicological effects may be summed to yield an effect-specific hazard index (HI) (EPA 1989). The effect-specific HI is an expression of the additivity of non-carcinogenic health effects. An effect-specific HI can be calculated by summing HQs for chemicals with similar toxicological effects (e.g., immunotoxicity). If the sum of all HQs for a given scenario evaluated in the EW HHRA is less than 1, no effect-specific HIs will be calculated because they would also not exceed 1. For scenarios with total sum HQs greater than 1, effect-specific HQs will be calculated. This is consistent with the approach for the LDW HHRA (Windward 2007c). Exposure scenarios in which the same receptor is exposed via multiple pathways simultaneously will be addressed by summing the RME estimates for those pathways. This approach will be applied to all direct sediment exposure scenarios that involved both dermal absorption and incidental sediment ingestion. In addition, excess cancer risk estimates will be summed across some potentially related scenarios (e.g., netfishing and seafood consumption).

CDIs will be presented with two significant figures, while excess cancer risks and HQs will be presented with only one significant figure. The former reflects the accuracy of the CDI equations, and the latter reflects the accuracy of the cancer SFs and reference doses, as per the EPA IRIS database. Sums of excess cancer risk estimates will be reported with one significant figure as well. For example, the sum of excess risk estimates of 2×10^{-4} and 3×10^{-5} will be reported as 2×10^{-4} , not 2.3×10^{-4} . Hazard indices (HIs, sums of HQs) will be presented with one significant figure if they are less than 1, or to the nearest integer if they are greater than 1. This is to allow the reader to follow summations. For example, HQs of 4 and 10 will be summed to an HI of 14, not 10. However, HQs of 0.01 and 0.001 will be summed to an HI of 0.01, not 0.011. This presentation is consistent with the LDW HHRA (Windward 2007c).

5.3 APPROACHES FOR ESTIMATION OF BACKGROUND CONTRIBUTION TO RISK ESTIMATES

When the chemicals of concern are determined, specific strategies for addressing potential background issues may be developed. It is likely that, as in the LDW, arsenic risk from seafood consumption will pose unacceptable risks. In the LDW HHRA (Windward 2007c), risk associated with arsenic background exposures were subtracted from risk associated with arsenic site exposures. For the LDW HHRA, unadjusted excess cancer risk estimates associated with arsenic exposure were first presented along with risk estimates for all other chemicals in the risk characterization. Then, in a separate analysis presented later in the risk characterization section, excess cancer risks associated with background were subtracted from the risk estimates for the LDW to estimate the incremental risks associated with arsenic in the LDW. The approach used for the LDW HHRA also will be employed for the EW, and the same arsenic tissue datasets will be appropriate for characterizing background for both sites. For the LDW HHRA, to evaluate background arsenic sediment exposure, twelve additional samples were collected from the Duwamish River upstream of the LDW. A UCL was calculated for these additional samples and used to estimate upstream risk. Incremental risks were then calculated as the difference between the LDW and upstream risk estimates for the direct contact sediment exposure scenarios. For tissue evaluation, tissue data from locations in Puget Sound were used rather than upstream of the LDW because there are species differences due to the freshwater conditions upstream of the LDW. For arsenic, background tissue samples were collected from other parts of Puget Sound that were either within the influence of the Asarco smelter or were not. Data from these field studies were used to calculate EPCs and risk estimates for both Asarco-influenced and non-Asarco-influenced exposures. Incremental risk estimates were then calculated for both conditions by subtracting the background risk estimate from the LDW risk estimates. The same procedure and same Asarco-influenced and non-Asarco-influenced datasets will be used in the evaluation of tissue arsenic background risks for the EW HHRA.

Approaches for other chemicals will likely be similar (e.g., tissue data would be from other parts of Puget Sound) if deemed necessary to evaluate. Incremental risk evaluations may be developed for other chemicals depending on the results of the risk characterization.

6 Uncertainty Assessment

Although some issues that will be evaluated in the uncertainty assessment are known, others will be determined through the development of the risk assessment. Issues associated with exposure analysis, toxicity assessment, and risk characterization will be addressed.

Uncertainty in the exposure point concentrations, such as potential differences in tissue concentrations across years and the impact of the inclusion of historical data on the risk assessment, will be evaluated. Uncertainties in the exposure scenarios will also include the impact of changing the assumptions regarding consumption of different species of clam. The uncertainty analysis will also include a discussion of uncertainties in the risk estimates resulting from the exclusion of the consumption of salmon. Seafood consumption rates based on the 95th percentile of seafood consumption for children reported in the Tulalip Tribes study (Toy et al. 1996) will be used to estimate risk associated with consumption of resident EW seafood. Risk estimates for a child tribal scenario based on Suquamish Tribe survey data (Suquamish Tribe 2000) will also be presented in the uncertainty analysis. Risk estimates using a totaling approach for total PCBs that includes one-half the sample-specific reporting limit for non-detect PCB Aroclors or congeners (for which the same Aroclor or PCB congener was detected elsewhere at the site in the same medium) will be explored. These will be compared to the risk estimates presented in the risk characterization section that will use total PCBs concentrations based on SMS data rules (see Section 3.2.2). In addition, risk estimates for COCs including only tissue data collected in 2008 will be explored to see how the inclusion of older data may have impacted risk estimates.

In the case of the EW intertidal bivalve data, the use of one UCL inclusive of all intertidal clam samples resulted in the highest and most health protective of the bivalve EPC estimates. A discussion of the uncertainties involved in computing alternative bivalve EPCs will be included in the uncertainty section of the HHRA. Risk estimates assuming that all bivalve consumption consists of a single species will also be explored.

Risks associated with pathways identified as complete but with low exposure and risk potential relative to other evaluated pathways (e.g., exposure to water during shore clamming) may be discussed qualitatively in the uncertainty section. Risks associated with chemicals that were never detected will be evaluated qualitatively in the uncertainty analysis. Other analyses will be added based on the findings of the risk characterization.

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Appendix A Data Management

AVERAGING LABORATORY REPLICATE SAMPLES

Chemical concentrations obtained from the analysis of laboratory replicate samples (two or more analyses of the same sample) will be averaged for a closer representation of the “true” concentration as compared to the result of a single analysis. Averaging rules are dependent on whether the individual results are detected concentrations or reporting limits (RLs) for undetected chemicals. If all concentrations are detected for a single chemical, the values are simply averaged arithmetically for the sample and its associate laboratory replicate sample(s). If all concentrations are undetected for a given parameter, the minimum RL is selected. If the concentrations are a mixture of detected concentrations and RLs, any two or more detected concentrations are averaged arithmetically and RLs ignored. If there is a single detected concentration and one or more RLs, the detected concentration is reported. The latter two rules are applied regardless of whether the RLs are higher or lower than the detected concentration.

LOCATION AVERAGING

Results of chemical concentrations of discrete samples collected at a single sampling location that are submitted to the laboratory as individual samples and analyzed separately will be averaged for the purposes of mapping a single concentration per location. The averaging rules used for location averaging are the same as for laboratory replicate samples described above. This type of averaging is performed when multiple sediment samples are collected from the same location at the same time. For example: a sample and its field duplicate sample, often referred to as a split sample (PSEP 1997).

SIGNIFICANT FIGURES AND CALCULATIONS

Analytical laboratories report results with various numbers of significant figures depending on the laboratory’s standard operating procedures, the instrument, the chemical, and the reported chemical concentration relative to the RL. The reported (or assessed) precision of each result is explicitly stored in the project database by recording the number of significant figures. Tracking of significant figures is used when calculating analyte sums and performing other data summaries. When a calculation involves addition, such as totaling PCBs, the calculation can only be as precise as the least precise number that went into the calculation. For example:

210 + 19 = 229 would be reported as 230 because although 19 is reported to 2 significant digits, the trailing zero in the number 210 is not significant.

When a calculation involves multiplication or division, the final result is rounded at the end of the calculation to reflect the value used in the calculation with the fewest significant figures. For example:

$59.9 \times 1.2 = 71.88$ would be reported as 72 because there are two significant figures in the number 1.2.

When rounding, if the number following the last significant figure is less than 5, the digit is left unchanged. If the number following the last significant figure is equal to or greater than 5, the digit is increased by 1.

Many of the Washington State Sediment Management Standards (SMS) chemical criteria are in units normalized to the TOC content in the sediment sample (i.e., milligrams per kilogram organic carbon [mg/kg OC]). Only samples with TOC concentrations greater than or equal to 0.5% or less than or equal to 4.0% are considered appropriate for OC normalization. Samples with TOC concentrations less than 0.5% or greater than 4.0% are compared to dry weight chemical criteria. Chemical concentrations originally in units of micrograms per kilogram ($\mu\text{g/kg}$) dry weight were converted to mg/kg OC using the following equation:

$$\frac{(C_{\mu\text{g/kg dry weight}}) \times (0.001 \text{ mg}/\mu\text{g})}{\text{TOC}}$$

Where:

C = the chemical concentration
TOC = the percent total organic carbon on a dry weight basis, expressed as a decimal (e.g., 1% = 0.01)

BEST RESULT SELECTION FOR MULTIPLE RESULTS

In some instances, the laboratory generates more than one result for a chemical for a given sample. Multiple results can occur for several reasons, including: 1) the original result did not meet the laboratory's internal quality control (QC) guidelines, and a reanalysis was performed; 2) the original result did not meet other project data quality objectives, such as a sufficiently low RL, and a reanalysis was performed; or 3) two different analytical methods were used for that chemical. In each case, a single best result is selected for use. The procedures for selecting the best result differ depending on whether a single or multiple analytical methods are used for that chemical.

For the same analytical method, if the results are:

- ◆ Detected and not qualified, then the result from the lowest dilution is selected, unless multiple results from the same dilution are available, in which case, the result with the highest concentration is selected.
- ◆ A combination of estimated and unqualified detected results, then the unqualified result is selected. This situation most commonly occurs when the original result is outside of calibration range, thus requiring a dilution.
- ◆ All estimated, then the "best result" is selected using best professional judgment in consideration of the rationale for qualification. For example, a

for precision would be preferred to a qualified result that is outside the calibration range.

- ◆ A combination of detected and undetected results, then the detected result is selected. If there is more than one detected result, the applicable rules for multiple results (as discussed above) are followed.
- ◆ All undetected results, then the lowest RL is selected.

If the multiple results are from different analytical methods, then the result from the preferred method specified in the quality assurance project plan (QAPP) or based on the consensus of the professional opinions of project chemists was selected.

The following rules are applied to multiple results from different analytical methods:

- ◆ For detected concentrations analyzed by the SVOC full-scan and selective ion monitoring (SIM) methods (i.e., PAHs), the highest detected concentration is selected. If the result by one method is detected and the result by the other method is not detected, then the detected result is selected for reporting, regardless of the method. If results are reported as non-detected by both methods, the undetected result with the lowest RL is selected. The SIM method is more analytically sensitive than the full-scan SVOC method, and the undetected results are generally reported at a lower RL by the SIM method than by the full-scan method. Therefore, the SIM method is selected for non-detected results unless an analytical dilution or analytical interferences elevated the SIM RL above the SVOC full-scan RL.
- ◆ Hexachlorobenzene and hexachlorocyclopentadiene are analyzed by EPA Methods 8081A, 8270, and/or 8270-SIM. The result from the method with the greatest sensitivity (i.e., lowest RL) is selected if all results are undetected. EPA Method 8081A results are generally selected, when available, because the standard laboratory RLs from this analysis are significantly lower than those from EPA Methods 8270 and 8270-SIM. When chemicals are detected, the detected result with the highest concentration is selected unless the detected concentration is qualified as estimated or tentatively identified, in which case the rule designating treatment of qualified and unqualified data would apply.

CALCULATED TOTALS

Total PCBs, total dichloro-diphenyl-trichloroethane (DDTs), total PAHs, and total chlordane are calculated by summing the detected values for the individual components available for each sample. For individual samples in which none of the individual components is detected, the total value is given a value equal to the highest RL of an individual component, and assigned the same qualifier (U or UJ), indicating an undetected result. Concentrations for the analyte sums are calculated as follows:

- ◆ **Total PCBs** are calculated, in accordance with the methods of the SMS, using only detected values for seven Aroclor mixtures.¹ For individual samples in which none of the seven Aroclor mixtures is detected, total PCBs are given a value equal to the highest RL of the seven Aroclors and assigned a U-qualifier indicating the lack of detected concentrations.
- ◆ **Total low-molecular-weight PAHs (LPAHs), high-molecular-weight PAHs (HPAHs), PAHs, and benzo(a)fluoranthenes** are also calculated in accordance with the methods of the SMS. Total LPAHs are the sum of detected concentrations for naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene. Total HPAHs are the sum of detected concentrations for fluoranthene, pyrene, benzo(a)anthracene, chrysene, total benzo(a)fluoranthenes, benzo(a)pyrene, indeno(1,2,3-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene. Total benzo(a)fluoranthenes are the sum of the b (i.e., benzo(b)fluoranthene), j, and k isomers. Because the j isomer is rarely quantified, this sum is typically calculated with only the b and k isomers. For samples in which all individual compounds within any of the three groups described above are undetected, the single highest RL for that sample represents the sum.
- ◆ **Total DDTs** are calculated using only detected values for the DDT isomers: 2,4'-DDD; 4,4'-DDD; 2,4'-DDE; 4,4'-DDE; 2,4'-DDT; and 4,4'-DDT. For individual samples in which none of the isomers are detected, total DDTs are given a value equal to the highest RL of the six isomers and assigned a U-qualifier, indicating the lack of detected concentrations.
- ◆ **Total chlordane** is calculated using only detected values for the following compounds: alpha-chlordane, gamma-chlordane, oxychlordane, cis-nonachlor, and trans-nonachlor. For individual samples in which none of these compounds is detected, total chlordane is given a value equal to the highest RL of the five compounds listed above and assigned a U-qualifier, indicating the lack of detected concentrations.

CALCULATION OF PCB CONGENER TEQS

PCB congener toxic equivalents (TEQs) are calculated using the World Health Organization (WHO) consensus toxic equivalency factor (TEF) values for mammals (Van den Berg et al. 2006) as presented in Table E-1. The TEQ is calculated as the sum of each congener concentration multiplied by the corresponding TEF value. When the congener concentration is reported as non-detected, then the TEF is multiplied by half the RL.

¹ Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260.

Table E-1. PCB congener TEF values

PCB CONGENER NUMBER	TEF VALUE FOR MAMMALS (unitless)
77	0.0001
81	0.0003
105	0.00003
114	0.00003
118	0.00003
123	0.00003
126	0.1
156	0.00003
157	0.00003
167	0.00003
169	0.03
189	0.00003

PCB – polychlorinated biphenyl

TEF – toxic equivalency factor

CALCULATION OF DIOXIN/FURAN CONGENER TEQS

Dioxin/furan congener TEQs are calculated using the WHO consensus TEF values (Van den Berg et al. 2006) for mammals as presented in Table E-2. The TEQ is calculated as the sum of each congener concentration multiplied by the corresponding TEF value. When the congener concentration is reported as undetected, then the TEF is multiplied by half the RL.

Table E-2. Dioxin/Furan congener TEF values for mammals

DIOXIN/FURAN CONGENER	TEF VALUE (unitless)
1,2,3,4,6,7,8-Heptachlorodibenzofuran	0.01
1,2,3,4,6,7,8-Heptachlorodibenzo- <i>p</i> -dioxin	0.01
1,2,3,4,7,8,9-Heptachlorodibenzofuran	0.01
1,2,3,4,7,8-Hexachlorodibenzofuran	0.1
1,2,3,4,7,8-Hexachlorodibenzo- <i>p</i> -dioxin	0.1
1,2,3,6,7,8-Hexachlorodibenzofuran	0.1
1,2,3,6,7,8-Hexachlorodibenzo- <i>p</i> -dioxin	0.1
1,2,3,7,8,9-Hexachlorodibenzofuran	0.1
1,2,3,7,8,9-Hexachlorodibenzo- <i>p</i> -dioxin	0.1
1,2,3,7,8-Pentachlorodibenzofuran	0.03
1,2,3,7,8-Pentachlorodibenzo- <i>p</i> -dioxin	1
2,3,4,6,7,8-Hexachlorodibenzofuran	0.1
2,3,4,7,8-Pentachlorodibenzofuran	0.3
2,3,7,8-Tetrachlorodibenzofuran	0.1

DIOXIN/FURAN CONGENER	TEF VALUE (unitless)
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1
Octachlorodibenzofuran	0.0003
Octachlorodibenzo-p-dioxin	0.0003

TEF – toxic equivalency factor

CALCULATION OF CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS

Carcinogenic polycyclic aromatic hydrocarbons (cPAH) values are calculated using potency equivalency factors (PEFs) (California EPA 1994). Similar to TEFs, PEFs relate the toxicity of certain PAH compounds to that of benzo(a)pyrene based on the individual PAH component's relative toxicity to benzo(a)pyrene. PEF values are presented in Table E-3. The cPAH is calculated as the sum of each individual PAH concentration multiplied by the corresponding PEF value. When the individual PAH component concentration is reported as non-detected, then the PEF is multiplied by half the RL.

Table E-3. cPAH TEF values

cPAH	PEF VALUE (unitless) ^a
Benzo(a)pyrene	1
Benzo(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.1
Chrysene	0.01
Dibenz(a,h)anthracene ^b	0.4
Indeno(1,2,3-cd)pyrene	0.1

cPAH – carcinogenic polycyclic aromatic hydrocarbon

TEF – toxic equivalency factor

^a PEFs for cPAHs were defined by the California Environmental Protection Agency, Office of Environmental Health Hazard Assessment (California EPA 1994). PEFs are available for PAHs that were not analyzed in EW sediments or tissue. The PEFs for these compounds are not shown here and are not used in this risk assessment.

^b The PEF was determined by California EPA by dividing the inhalation unit risk factor for this compound by the inhalation unit risk factor for benzo[a]pyrene.

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